The American Midland Naturalist
Published Bi-Monthly by The University of Notre Dame, Notre Dame, Indiana

VOL. 31 MAY, 1944 NO. 3

Biostratigraphic Relations of Some North Texas Trinity and Fredericksburg (Comanchean) Foraminifera*

Frank E. Lozo, Jr.

Introduction and Acknowledgments

Lower Cretaceous sediments of North Texas contain well-developed foraminiferal faunas, although biostratigraphic[1] literature on the region deals mainly with larger fossils, especially mollusks and echinoderms. Papers on Foraminifera are primarily devoted to descriptions of new species, the relationships between fossils and containing strata being given secondary treatment or omitted. The foraminiferal faunas of some formations have not been recorded at all.

This paper records and discusses Foraminifera of the Trinity and Fredericksburg groups in an effort to trace the degree to which different facies reflect environmental and depositional changes, and to determine what some of those changes are. New species are described in order that they may be given their place in the general picture.

In preparing this paper I have used unpublished as well as published data, foraminiferal samples, and the criticisms and suggestions of many geologists. Some of these contributions are acknowledged, but I am equally grateful for those that are not.

Financial aid in field work has come from the Mrs. A. H. Phillips Fund of Princeton University, from the Department of Geology of that institution, and from my father, F. E. Lozo. Doctors B. F. Howell and Erling Dorf of Princeton University and W. M. Winton, W. G. Hewatt and Gayle Scott of Texas Christian University have given counsel and assistance during preparation of the manuscript. Many species of Foraminifera have been determined by Joseph A. Cushman, Helen Jeanne Plummer and R. Wright Barker.

* A dissertation submitted to the Department of Geology of Princeton University in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

1 Biostratigraphy is that phase of paleontology which relates fossils to their containing strata. For an excellent discussion of biostratigraphic terminology see R. M. Kleinpell's *Miocene Stratigraphy of California*, Am. Assoc. Petroleum Geologists: 87-99, 1938.

Location and Physical Features

The north Texas area treated in this report and shown by the index map (Fig. 1) is bounded on the north by Red River, roughly on the east, south, and west by the ninety-seventh meridian, the thirty-first parallel, and the ninety-eighth meridian respectively.

The attitude, composition, and stratigraphic position of the lithologic units of the Trinity and Fredericksburg groups are intimately related to the topographic units and features of the area studied. For the terminology of these topographic subdivisions later workers are indebted to R. T. Hill (1901). Additional discussions on soil types, surface features and physiographic classification with other major divisions of the United States are provided by the works of Johnson (1931) and Fenneman (1931, 1938).

The physiographic diagram (Fig. 2A) and structural diagram (Fig. 2B) illustrate the major physical features of the area studied. With the exception

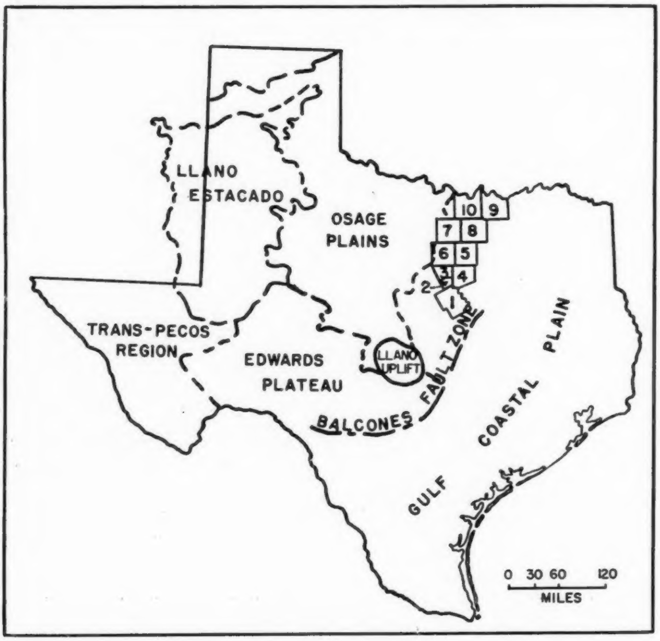

Fig. 1. Sketch map of Texas showing the counties treated in this study and some neighboring physiographic provinces, geographic areas and structural features. Counties: 1—Bosque; 2—Somervell; 3—Hood; 4—Johnson; 5—Tarrant; 6—Parker; 7—Wise; 8—Denton; 9—Grayson; 10—Cooke. (Modified after figs. 3 and 4, Univ. Texas Bull. 3232).

of the Sherman syncline and Preston anticline in northern Cooke and Grayson counties, the Comanchean rocks show little apparent deviation from the original depositional attitude. Over most of the area the strike is north-south with an eastward regional dip of about 50 to 100 feet to the mile.

Fig. 2A. Physiographic diagram of a portion of north Texas.

Stratigraphy

The outcropping Comanchean series of the Texas Cretaceous is divided into three groups. From below upward, these are the Trinity, Fredericksburg, and Washita. Each of the groups is distinctive in faunal and lithologic content. Although the sediments and fauna of the Washita group are excluded

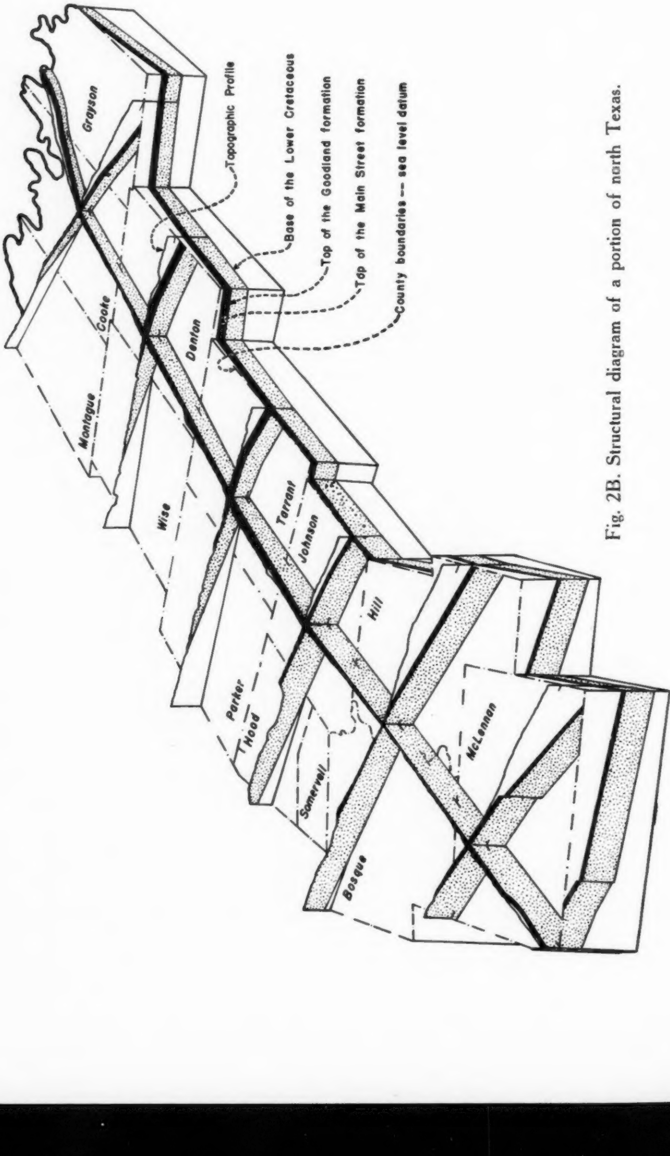

Fig. 2B. Structural diagram of a portion of north Texas.

from this report, the formational names are listed because of occasional references. The following chart lists the groups, formations, and intra-areal correlation. (Note Fig. 3.)

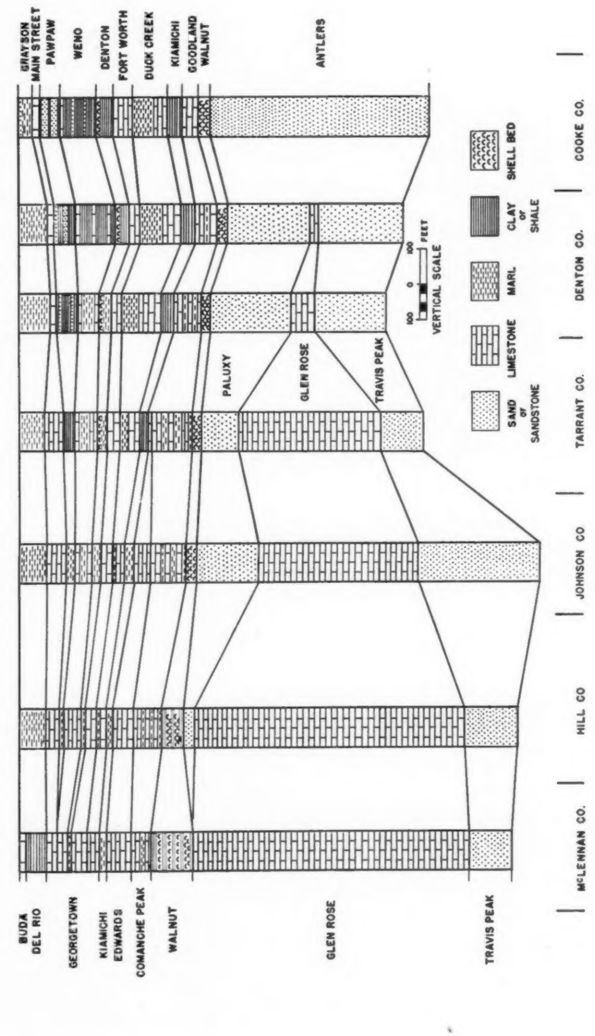

Fig. 3. Lithologic and thickness variations of the Comanchean formations of north Texas.

	Brazos River McLennan County	Trinity River Tarrant County	Red River Grayson County
WASHITA	Buda, Del Rio	Grayson	Grayson
	Georgetown	Main Street	Main Street
		Pawpaw	Pawpaw
		Weno	Weno
		Denton	Denton
		Fort Worth	Fort Worth
		Duck Creek	Duck Creek
FREDRICKSBURG	Kiamichi	Kiamichi	Kiamichi
	Edwards		
	Comanche Peak	Goodland	Goodland
	Walnut	Walnut	Walnut
TRINITY	Paluxy	Paluxy	Antlers
	Glen Rose	Glen Rose	
	Travis Peak	Travis Peak	

TRINITY GROUP

Sediments of the Trinity group in north Texas reflect two conditions of deposition. The Travis Peak sands were deposited by a shallow sea transgressing northward on an old land surface of variable relief. The sediments resulting from this transgression are coarse, sandy, conglomeratic and otherwise marginal in nature.

To the south and seaward of this sandy phase, the Glen Rose limestones were being laid down. Thus the Glen Rose limestone to the south is only the seaward facies, in part, of the Travis Peak sands to the north. The area of Glen Rose deposition may be likened to a calcareous mud flat such as the shoals found in the vicinity of the Bahama Islands today. The water was extremely shallow and the remains of animals restricted to this habitat are abundant.

Overlying the Glen Rose limestone and interfingering with the upper members of the latter in the vicinity of Wise County are the Paluxy sands. Alternate interfingering of the lower sands of the Paluxy with upper wedges of the Glen Rose, therefore, does not represent a definite time level at the contact of the two formations. Rather, the Paluxy composes the sandy shoreward facies of the upper Glen Rose. Scott (1930, p. 50) confirms this interpretation, first given by Hill (1901, p. 170). These uppermost sands of the Trinity group, the Paluxy formation, plus some of the upper Glen Rose members in this area, have been interpreted as deposits of the regressive phase of the late Trinity seas by Scott (1930, p. 52).

North of Wise County, where the limestone facies of the Glen Rose disappears, the sands of the Travis Peak and Paluxy combine to form the Antlers sand of the Red River region.

Travis Peak formation.—The marginal facies only is present in the area studied and consists of gravel, conglomerate, sandstones, sands, sandy clays, grits, and packsands largely made of pure quartz. Fossils in this basal formation are few; most of them are bone fragments too poorly preserved for identification with occasional fragments of carbonized or silicified wood. No microfossils have been reported and no outcrop samples of the marginal facies of the formation were collected.

Glen Rose formation.—The contacts of the Glen Rose formation are gradational with the Travis Peak sands below and the Paluxy sands above. The Glen Rose outcrops in a dendritic pattern through the middle of Bosque, Somervell, and Hood counties, the western part of Parker and the southern and central area of Wise County, disappearing a few miles northwest of Decatur. North of Decatur the limy facies of the Glen Rose is absent on the surface, though it appears at the surface again in southwestern Arkansas.

Although the formation is mainly limestone, clays, sandy clays, and sands occur abundantly throughout the formation. These members are seldom thick or persistent over large areas. The Glen Rose thickens to the south, with the replacement of sands above and below by limestone members, and also probably by thickening of individual strata. In the vicinity of Waco the formation approaches a thickness of 800 feet and the Paluxy sands have been almost entirely replaced.

A microfossil zonation of the Glen Rose is lacking. The large *Orbitolina concava texana* (Roemer), perhaps the best known of Texas Comanchean Foraminifera, is known from outcrops to occur in two levels in the Parker County area. Scott (1930, p. 43) reports these zones near the base and about the middle of the formation. Oogonia of charophytes have been reported by Winton (1925, p. 64) from Denton County wells but I have observed none in outcrop material. Vanderpool (1928a) has described several species of Ostracoda from the Glen Rose near Weatherford, Parker County.

The following Foraminifera have been found in the Glen Rose formation of north Texas:

Conorbina conica n. sp.	*Orbitolina concava texana* (Roemer)
Haplophragmoides trinitensis n. sp.	*Miliolidae* (indeterminate)
Lituola inflata n. sp.	and others inadequately studied

Paluxy formation.—This formation consists of fine-grained, unconsolidated, homogeneous quartz sand which is locally crossbedded and laminated. It thins to the south along the outcrops and is virtually absent at the Brazos River. No microfossils have been reported from these sands and I have observed no Foraminifera in samples collected immediately below the Walnut and above the Glen Rose members from several localities.

Antlers formation.—North of the latitude of Decatur, Wise County, the Trinity group is composed of the Antlers sand. It is a fine-grained, rounded, quartz packsand with clay lentils varying in thickness scattered throughout the formation. The Antlers is the nearshore and beach facies of the Trinity sea as the latter transgressed and then regressed from the area.

Although my samples from the uppermost sands of the Antlers contained no microfossils, Vanderpool (1933) records a locality 3 miles north of Marietta, Oklahoma, from which eight genera and species of Comanchean Foraminifera have been collected. The species recognized by Vanderpool are *Ammobaculites subgoodlandensis* Vanderpool, *Reophax subgoodlandensis* Vanderpool, *Textularia conica* d'Orbigny, *Planulina* sp., *Ramulina* sp., *Lituotuba* sp., *Vaginulina intumescens* Reuss, and *Patellina subcretacea* Cushman and Alexander. Through the courtesy of Helen Tappan Loeblich it has been possible to examine material from this locality. Four species of the above from Vanderpool's Paluxy beds (here considered Antlers) have been found in samples of the Walnut formation from a locality east of Decatur, namely

Ammobaculites subgoodlandensis Vanderpool
Vaginulina intumescens Reuss
"*Textularia conica*" (=*T. rioensis* Carsey)
"*Patellina subcretacea*" (=*Conorbina conica* n. sp.)

Since the first three of these species have not been observed below the Walnut formation, with the exception of the Marietta locality, it is thought that the sub-Goodland yellowish sandy shales of this locality are Fredericksburg in age and represent the marginal, nearshore facies of the Walnut formation to the south.

FREDERICKSBURG GROUP

Following the bathymetric classification proposed and defined by Scott (1940b), the seas of Fredericksburg time were epineritic, or shallow neritic, with bottom depth varying between 7 and 20 fathoms. Two dominant types of epineritic sub-facies are present in the Fredericksburg group: (1) oyster beds, as in the upper Kiamichi, especially of the Red River region and in the Walnut; and (2) the marls, marly limestones and limestones of the Goodland, and clays with thin flaggy sandstones as found in the Kiamichi. The oyster bed facies is more characteristic of slightly shallower shoreward conditions than the limestone-marl facies.

Walnut formation.—The Walnut formation, in this report, is limited to the calcareous sediments, including the shell beds, between the Goodland limestones above and the sands of the Paluxy-Antlers below. This is the concept of the formation as expressed by Scott and Hawley (in Adkins, 1932, p. 330). Thompson (1935) included arenaceous clay-marls here assigned to the Goodland in his definition of the formation. Other authors (Winton and Adkins, 1920) have included part of the upper sands of the Paluxy-Antlers of this report in the Walnut formation. Fredericksburg fossils have been found in sub-Goodland sandy clays indicating that these beds, in part, are probably Fredericksburg in age. South of Johnson County, marls and limestones become a greater part of the formation and the oysters, mainly *Gryphaea* and *Exogyra*, are proportionately fewer. This may indicate deposition in deeper water than that of the more northern facies.

The following Foraminifera have been observed in north Texas Walnut samples:

Ammobaculites goodlandensis Cushman and Alexander
Ammobaculites laevigata n. sp.
Ammobaculites subcretaceus Cushman and Alexander
Ammobaculites subgoodlandensis Vanderpool
Bolivina cf *textularioides* Reuss
Bullopora laevis (Sollas)
Conorbina conica n. sp.
Flabellammina alexanderi Cushman
Lingulina furcillata Berthelin
Lituola inflata n. sp.
Patellina subcretacea Cushman and Alexander
Spiroplectammina alexanderi Lalicker
Textularia rioensis Carsey
Vaginulina intumescens Reuss
Verneuilina schizea Cushman and Alexander

Goodland formation.—In the Brazos River Valley, middle Fredericksburg deposits are divided into two limestone formations. The upper, or Edwards, beds are classified as zoogene, or reef-bottom, deposits and were laid down in extremely shallow water. Rudistids and corals are the chief faunal components of this facies; a poorly preserved foraminiferal fauna of reef-habitat aspect is known but undescribed. The lower, or Comanche Peak, beds form a limy-marly facies indicative of slightly greater bottom depth. This lower facies is the equivalent of and is the same as that of the Goodland to the north. My outcrop samples are from the Goodland-Comanche Peak facies only.

Samples from the Goodland yield the largest number of foraminiferal species and individuals of the three Fredericksburg formations. The following species are common to the Goodland beds:

Ammobaculites goodlandensis Cushman and Alexander
Ammobaculites laevigata n. sp.
Ammobaculites subcretaceus Cushman and Alexander
Ammobaculites subgoodlandensis Vanderpool
Bullopora irregularis n. sp.
Bullopora laevis (Sollas)
Conorbina conica n. sp.
Coskinolina adkinsi Barker
Dentalina communis d'Orbigny
Dentalina debilis (Berthelin)
Flabellammina alexanderi Cushman
Frankeina goodlandensis Cushman and Alexander
Globigerina washitensis Carsey
Haplophragmoides globosa n. sp.
Lingulina furcillata Berthelin
Lituola camerata n. sp.
Lituola inflata n. sp.
Nodosaria aff. *obscura* Reuss
Palmula leai Loeblich and Tappan
Patellina subcretacea Cushman and Alexander
Spiroplectammina alexanderi Lalicker
Spiroplectammina goodlandana Lalicker
Spiroplectammina scotti Cushman and Alexander
Textularia rioensis Carsey
Vaginulina intumescens Reuss
Vaginulina marginulinoides Reuss
Verneuilina schizea Cushman and Alexander

Kiamichi formation.—Throughout the north Texas-southern Oklahoma outcrop area, this formation consists of thin limestone members, marl, sandy flags and shell aggregates composed mainly of *Gryphaea navia* Hall. The southernmost outcrops are more marly, particularly in the lower portions, than those of the Grayson County area and indicate slightly deeper seas over the southern area. Progressing northward, the oyster aggregates become quantitatively more important and clay takes the place of much of the marl. Such a change in lithology seems to be due primarily to a shallowing of the seas and to deposition nearer shore. The quantitative change in the microfauna supports this conclusion. In the southern area, where sediments are dominantly marl, Foraminifera are numerous and varied, holothurian plates and other remains

of echinoderms are present and fish remains are lacking. Samples from the northern area (the oyster bed sub-facies) are very lean in Foraminifera but rich in fish teeth and other bones, while Ostracoda dominate the fossil percentage. Most of the northern samples are also rich in pyrite nodules. In the shallower waters that covered the Red River region during late Fredericksburg time, the fauna probably was repeatedly subjected to unfavorable conditions—possibly as a result of pyrite genesis—which could be effectively endured only by such organisms as oyster, fish and ostracodes.

The following Foraminifera have been found in Kiamichi outcrop material:

Ammobaculites goodlandensis Cushman and Alexander
Ammobaculites laevigata n. sp.
Ammobaculites subcretaceus Cushman and Alexander
Astacolus comanchensis n. sp.
Bullopora irregularis n. sp.
Dentalina communis d'Orbigny
Flabellammina alexanderi Cushman
Frankeina acutocarinata Alexander and Smith
Frankeina goodlandensis Cushman and Alexander
Globigerina planispira Tappan
Globigerina washitensis Carsey
Lingulina furcillata Berthelin
Lituola inflata n. sp.
Marginulina cyprina Vieaux
Marginulina tenuissima Reuss
Palmula leai Loeblich and Tappan
Placopsilina longa Tappan
Spiroplectammina scotti Cushman and Alexander
Spiroplectammina cf. *whitneyi* Cushman and Alexander
Textularia rioensis Carsey
Trochammina depressa n. sp.
Vaginulina intumescens Reuss
Virgulina primitiva Cushman

Descriptions of Outcrops

The outcrops described in this report are designated by the author's station numbers. The index road maps (Figs. 4-13) are modified from county base maps, 1936 edition, prepared by the State Highway departments of Texas and Oklahoma in cooperation with the United States Department of Agriculture, Bureau of Public Roads.

COOKE COUNTY

Sta. T-48-2 (Fig. 4).—Lower 15 feet of the Kiamichi formation in a northward-facing bank of a stream tributary to Elm Fork of Trinity River, 300 feet east of Myra-Lindsay road one mile[2] southwest of St. Peter's Church, Lindsay. Three samples of the fissile black shale were collected and spotted from the section given in the Univ. Texas Bull. 2710, p. 22, and the holotype of *Trochammina depressa*, n. sp., was chosen from this locality.

Sta. T-84-6 (Fig. 4).—Kiamichi exposure along south bank of Dry Elm Creek, a tributary of Elm Fork of Trinity River, 200 feet south of roadside park and concrete highway bridge at distance 9 miles east of Gainesville courthouse on Gainesville-Muenster road (US 82-Texas 5),[3] 3.4 miles east of Lindsay.

2 All mileages in the location of stations are speedometer road mileages unless otherwise indicated.

3 Federal highways are designated by US and number, state highways by Texas and number.

Sta. T-48-7 (Fig. 4).—Goodland exposure along north bank of Elm Fork of Trinity River, 2.6 miles south of the MKT railway station of Myra. Two samples were taken, one from blue sandy shale near the stream bed level just below and east of the old steel highway bridge; the other from blue shale and brown clay about 300 yards west of the road and about 20 feet below the top of the section as given in Univ. Texas Bull. 2710:16.

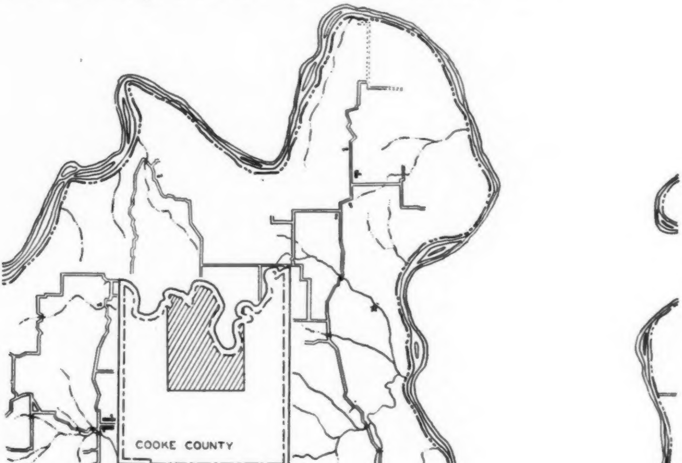

Fig. 4. Sketch map of a portion of Cooke County showing the locations of stations T-48-2, T-48-6, and T-48-7.

GRAYSON COUNTY

Sta. T-49-7 (Fig. 5).—Walnut exposure of 6 feet of blue sandy clay just north of small bridge over a tributary of Little Mineral Creek on Fink-Preston road, 4.15 miles north of Fink. Massive Goodland limestone outcrops in the road on both sides of the creek.

Sta. T-49-8 (Fig. 5).—Walnut exposure of blue-brown sandy clay 6 feet in thickness immediately below massive Goodland limestone at crest of hill in highway cut 1.5 miles west of Preston and 0.4 miles west of junction of main road west from Preston and main road north from Fink.

Sta. T-49-10 (Fig. 5).—Kiamichi exposure of about 36 feet of dark blue to light gray shales, hard gray limestones, and shell aggregates along the north bank of Shawnee Creek, immediately below the spillway of Randell Lake, 4.9 miles northwest of Denison, measured from the junction of US 75 and Texas 91 in the city. Five samples of the shale in the section (described in Okla.

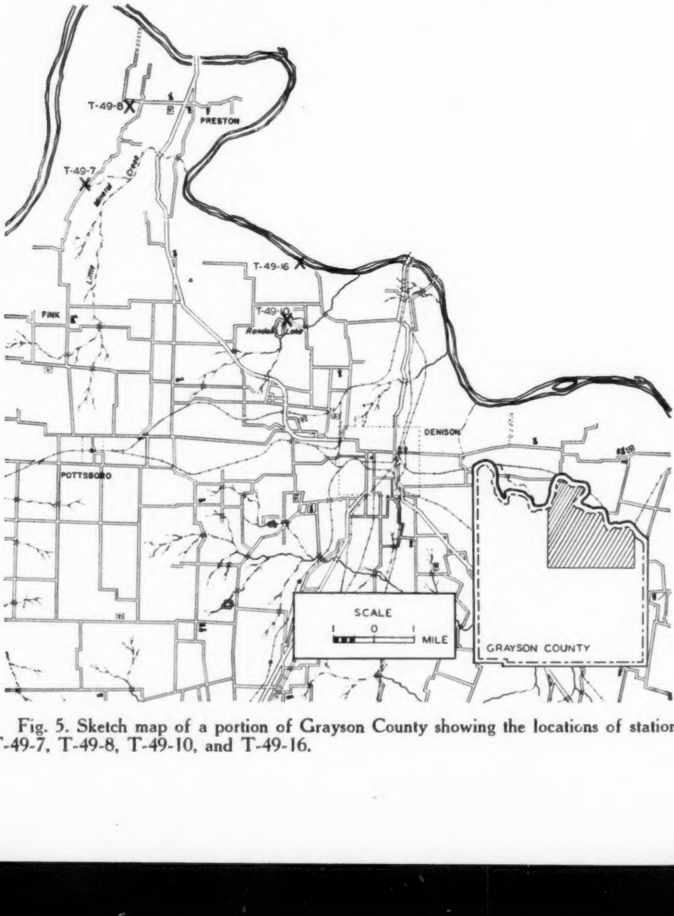

Fig. 5. Sketch map of a portion of Grayson County showing the locations of stations T-49-7, T-49-8, T-49-10, and T-49-16.

Geol. Surv. Bull. 47:25-26) were collected. The hypotype of *Marginulina tenuissima* Reuss is from this outcrop.

Sta. T-49-16 (Fig. 5).—Entire exposure of the Kiamichi formation, about 50 feet of black fissile shale with thin white limestone ledges in the lower portion and thick gray-brown shell limestone ledges in the upper portion, at the site of the new dam across Red River about 5 miles north of Denison. The fauna of the Kiamichi and Duck Creek of this exposure is treated in some detail in a recent paper by the writer (1943).

DENTON COUNTY

Sta. T-63-1 (Fig. 6).—Lower Goodland brown marls and shales with limy intercalations exposed in east bank of Denton Creek about 300 feet north of concrete highway bridge, 12.4 miles east of Decatur (Wise County) courthouse on Dry Weather Route of Denton-Decatur road (Texas 24). Two samples of the brown marls, one from the level of the stream bed, the other 15 feet above, were examined. The hypotype of *Ammobaculites goodlandensis* Cushman and Alexander was selected from this exposure.

Sta. T-63-5 (Fig. 6).—Upper Goodland gray marls and white limestones along west bank of a tributary of Clear Creek, 1.1 miles west of Bolivar and

Fig. 6. Sketch map of a portion of Denton County showing the locations of stations T-63-1, T-63-5, and T-63-6.

about 150 feet north of old steel bridge on main road west from Bolivar. *Nodosaria* aff. *obscura* Reuss is figured in this paper from these strata.

Sta. T-63-6 (Fig. 6).—Upper Goodland exposure of about 15 feet of massive limestones with partings of blue marl along the south bank of Clear Creek, 0.8 miles west of Bolivar or 5 miles west of Sanger on main Sanger-Bolivar continuation westward. This is the type locality of *Cythereis mahonae* Alexander (Univ. Texas Bull. 2907:18), and is probably the type locality of *Spiroplectammina goodlandana* Lalicker (Contr. Cushman Lab. Foram. Res. 11(1):2).

WISE COUNTY

Sta. T-64-2 (Fig. 7). —Goodland formation roadside exposure of 8 feet of shell aggregate, brown marls and limy intercalations, 6.7 miles southeast of Decatur courthouse on the Decatur-Fort Worth highway (US 81).

Sta. T-64-3 (Fig. 7).—Paluxy sands are exposed at this and the following station immediately above and below thin tongues of fossiliferous Glen Rose

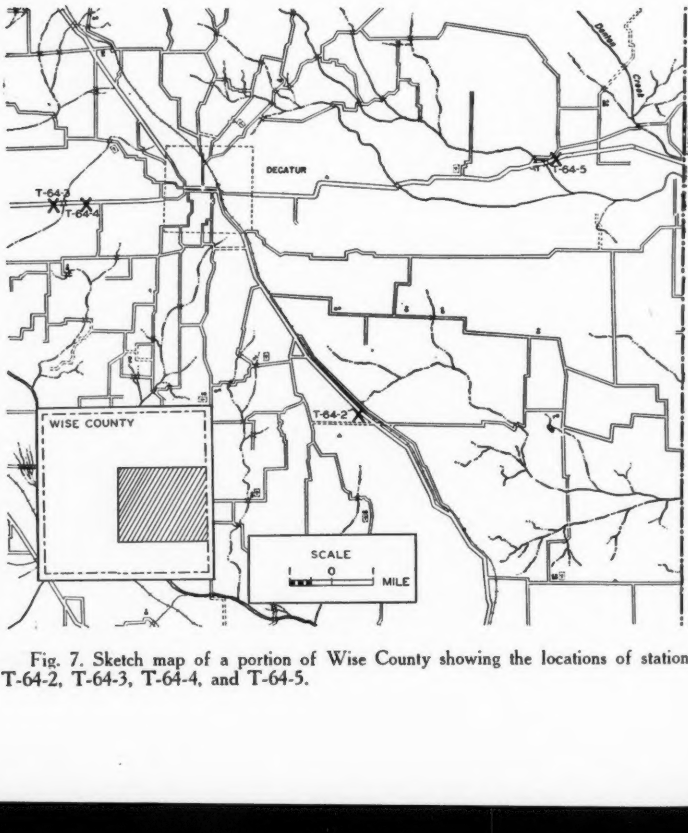

Fig. 7. Sketch map of a portion of Wise County showing the locations of stations T-64-2, T-64-3, T-64-4, and T-64-5.

limestone. This roadside locality is 3.8 miles west of the Decatur courthouse on the Decatur-Bridgeport highway (Texas 24).

Sta. T-64-4 (Fig. 7).—Paluxy sands in roadside exposure on south side of Decatur-Bridgeport road 3.1 miles west of Decatur courthouse. This and the preceding station were combined as Locality 8 of the SEPM-AAPG field trip of March 24, 1929.

Sta. T-64-5 (Fig. 7).—Excellent, almost entire, Walnut section in roadside just west of hill crest, 9.2 miles east of Decatur courthouse on Decatur-Denton (Dry Weather Route) highway (Texas 24). Hypotypes of *Ammobaculites subgoodlandensis* Vanderpool, *Textularia rioensis* Carsey, *Verneuilina schizea* Cushman and Alexander, *Bullopora laevis* (Sollas), and *Bolivina* cf. *textilarioides* Reuss of this paper came from this outcrop.

PARKER COUNTY

Sta. T-84-1 (Fig. 8).—Middle Glen Rose stream bed exposure of *Orbitolina*-bearing limestones and gray marls, and stream bank cut of blue and brown shale, just north of old steel bridge over Sanchez Creek, 5.7 miles southwest of Weatherford courthouse on Weatherford-Dennis road. This is the type locality of *Haplophragmoides trinitensis*, n. sp. and *Conorbina conica*, n. sp.

Sta. T-84-2 (Fig. 8).—Upper Glen Rose limestones and marls in roadside exposure, 5.2 miles southwest of Weatherford courthouse on Weatherford-Dennis road.

Sta. T-84-3 (Fig. 8).—Basal Glen Rose in roadside exposure on southern side of Weatherford-Dennis road, 9.4 miles southwest of Weatherford courthouse.

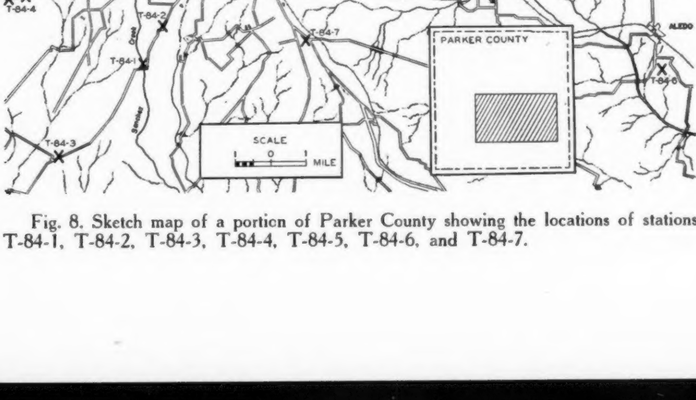

Fig. 8. Sketch map of a portion of Parker County showing the locations of stations T-84-1, T-84-2, T-84-3, T-84-4, T-84-5, T-84-6, and T-84-7.

Sta. T-84-4 (Fig. 8).—Middle Glen Rose limestones and marls in roadside exposures 7.5 and 7.0 miles west-southwest of Weatherford courthouse on Weatherford-Strawn highway (Texas 89). This exposure is within the type area and may be the exact locality of Vanderpool's species *Bairdia dorsoventrus, B. glenrosensis, Cytheridea rotundus, Cytheropteron (Eocytheropteron) trinitiensis, Pontocypris perforata,* and *Paracypris weatherfordensis* Jour. Pal. 2(2):98-106).

Sta. T-84-5 (Fig. 8).—Walnut clay-marls and shell aggregates in roadside exposure on Fort Worth-Weatherford highway, 10.2 miles east of Weatherford courthouse or 13.0 miles west of the junction of the Fort Worth-Weatherford (US 80) and Fort Worth-Granbury (US 377) highways. This junction is about 1.5 miles west of the Fort Worth city limits and is locally known as "Ball's Corner."

Sta. T-84-6 (Fig. 8).—Upper and middle Walnut clay-marls and shell limestones in west bank of artificial lake formed by impounding south-flowing tributary of the Clear Fork of Trinity River, 1.0 mile south-southeast of Aledo.

Sta. T-84-7 (Fig. 8).—Upper Goodland roadside exposure 5.1 miles south-southeast of Weatherford court house on Weatherford-Cleburne highway (Texas 122). Paratypes of *Lituola camerata,* n. sp., and *L. inflata,* n. sp., were selected from this exposure.

TARRANT COUNTY

Sta. T-85-2 (Fig. 9).—Entire section of Kiamichi exposed in deep roadside cuts on "Steve Foundry Road" or "Old Granbury Road," 1.3 miles southwest of the intersection of this road with Montgomery Street in Fort Worth. Five samples of the dark blue-brown or yellowish shales and clays were collected. This is Station 5 and Station 2305 of Alexander (Univ. Texas Bull. 2907:20, and Jour. Pal. 7(2):212-213) and the type locality of the following species: *Bairdia roundyi, Cytheridea bairdioides, Cytheropteron (Eocytheropteron) tumidum,* and *C. (E.) semiconstrictum.* From this locality the holotype of *Astacolus comanchensis,* n. sp., a paratype of *Trochammina depressa,* n. sp., and hypotypes of *Palmula leai* Loeblich and Tappan, *Flabellammina alexanderi* Cushman, *Spiroplectammina scotti* Cushman and Alexander, and *S.* cf. *whitneyi* Cushman and Alexander are illustrated in this paper.

Sta. T-85-4 (Fig. 9).—Main Street gray marls and limestones and Pawpaw brown clays, 0.2 mile east of Sycamore Creek on Gustine Street, Fort Worth, whose eastern extension as Wylie Avenue passes near the United States Public Health Service Hospital. Hypotypes of *Haplostiche texana* (Conrad) and *Placopsilina longa* Tappan have been selected from the uppermost 2 feet of the Pawpaw in the roadside exposure at the crest of the hill.

Sta. T-85-7 (Fig. 9).—Upper Goodland blue marls and white limestones exposed in cut on north border of Lancaster Yards (T. & P. RR.) 50 to 75 feet south of the "Stove Foundry Road," at a point 2.0 miles southwest of the

intersection of this road with Montgomery Street, Fort Worth. The road cut at this point exposes an excellent unconformity of Quaternary gravels on an eroded Goodland surface. This station provided the hypotype of *Spiroplectammina alexanderi* Lalicker.

Sta. T-85-8 (Fig. 9).—Entire Goodland section (with exception of concealed 10 feet near the base) exposed just north and above the Lake Worth Dam and below the dam apron. The dam is 5.5 miles (airline) northwest of the Fort Worth courthouse. The section as given in Univ. Texas Bull. 1931: 29-30, measures 117 feet. This is Station 1 of Alexander (Univ. Texas Bull. 2907:17) and the type locality of *Cythereis carpenterae*. Cushman and Alexander (Contr. Cushman Lab. Foram. Res. 6(1):1-10, and 5(3):62) described the following Foraminifera from this locality: *Ammobaculites subcretaceus, Spiroplectammina scotti, S. whitneyi, Verneuilina schizea,* and *Frankeina good-*

Fig. 9. Sketch map of a portion of Tarrant County showing the locations of stations T-85-2, T-85-4, T-85-7, T-85-8, T-85-13, T-85-14, T-85-15, T-85-16, and T-85-17.

landensis. Specimens from the exposure illustrated in this paper are the holotype of *Haplophragmoides globosa*, n. sp., the holotype and several paratypes of *Lituola camerata*, n. sp., and hypotypes of *Ammobaculites subcretaceus*, *Spiroplectammina goodlandana* Lalicker, *Textularia rioensis* Carsey, *Dentalina communis* d'Orbigny, and *Vaginulina marginulinoides* Ruess.

Sta. T-85-13 (Fig. 9).—Upper Goodland marls and limestone in roadside cuts on "Stove Foundry Road," 3.8 miles southwest of intersection of this road with Montgomery Street. This locality, known as "Cragin Knobs," consists of several Goodland promontories truncated by the road cut. This is Station 2 and 2302 of Alexander (Univ. Texas Bull. 2907:1-18 and Jour. Pal. 7(2): 212), and is the type locality of *Cytherella scotti, Bythocypris goodlandensis, Cytheridea goodlandensis, Cythereis fredericksburgensis, Cytheropteron (Eocytheropteron) howelli, C. (E.) pirum, C. (E.) paenorbiculatum, C. (Cytheropteron) bicornutum*, and *Cytherella fredericksburgensis* (Am. Midland Nat. 13(5):308-309). Foraminiferal holotypes from this locality are *Flabellammina alexanderi* Cushman (Contr. Cushman Lab. Foram. Res. 4(1):1-2), *Ammobaculites goodlandensis* Cushman and Alexander (l.c., 6(1):8), and *Spiroplectammina alexanderi* Lalicker (l.c., 11(1):2). Paratypes of *Haplophragmoides globosa*, n. sp., and *Conorbina conica*, n. sp., and hypotypes of *Frankeina goodlandensis* Cushman and Alexander, *Dentalina debilis* (Berthelin) and *Lingulina furcillata* Berthelin were selected from this outcrop.

Sta. T-85-14 (Fig. 9).—Upper Goodland limestones and blue marls in the east bank of Mary's Creek at the concrete bridge on the Fort Worth-Weatherford highway (US 80) 4.7 miles west of the junction of this highway with the Fort Worth-Granbury highway (US 377). This is Station 3 of Alexander (Univ. Texas Bull. 2907:18), and the type locality for *Virgulina primitiva* Cushman (Cushman Lab. Foram. Res., Special Publ. 6:46) and *Bullopora irregularis*, n. sp.

Sta. T-85-15 (Fig. 9).—Upper portion of Goodland, entire section of Kiamichi and basal Duck Creek, exposed in cuts on east side of Westover Hills Road, a northwest extension of Byers Avenue. The Westover Hills Town Hall is visible due west of this locality. This is Locality 4 of the SEPM-AAPG field trip of March 23, 1929, and the type locality of *Patellina subcretacea* Cushman and Alexander (Contr. Cushman Lab. Foram. Res. 6(1): 10). One paratype of *Lituola camerata* n. sp. came from this exposure.

Sta. T-85-16 (Fig. 9).—Basal and lower Goodland marls and limestones along the White Settlement Road and in banks east of a small stream flowing into Lake Worth, 10.4 miles (airline) due west and 0.8 miles due north (airline) of the Fort Worth courthouse. This is TCU locality M-206. A hypotype of *Ammobaculites subgoodlandensis* Vanderpool is figured from this exposure.

Sta. T-85-17 (Fig. 9).—Kiamichi marls and clays in roadside exposure of "Old Azle Road" or "Ten Mile Bridge Road," 8.4 miles (airline) northwest of the Fort Worth courthouse. The road at this point sections the Kiamichi and passes north and northwest through the Goodland escarpment. The section

is given in Univ. Texas Bull. **1931**:35. *Vagulina intumescens* Reuss figured in this paper came from these strata.

JOHNSON COUNTY

Sta. T-99-3 (Fig. 10).—Kiamichi and Comanche Peak formations exposed in roadside cuts along Cleburne-Glen Rose highway (US 67) via Bono (Wet Weather Route), 7.1 miles southwest of Bono and approximately 0.5 mile east of Johnson-Somervell county line. The road at this point cuts through the Edwards Escarpment, locally known as "The Mountain," and exposes the

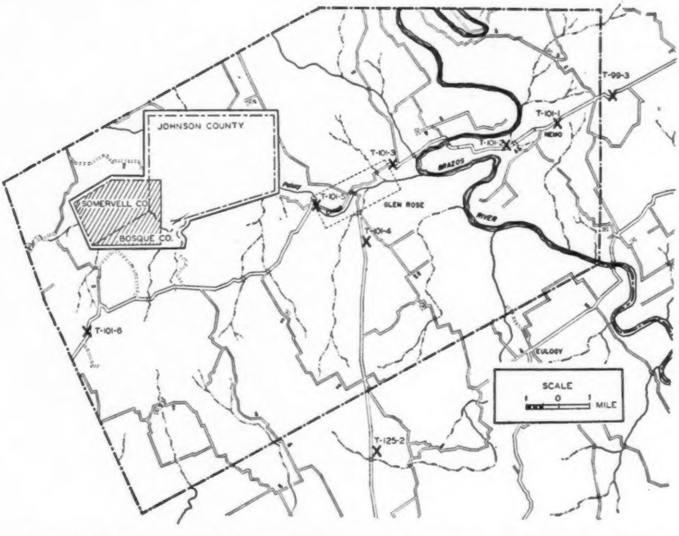

Fig. 10. Sketch map of Somevell County and portions of Johnson and Bosque counties showing the locations of stations T-99-3, T-101-1, T-101-2, T-101-3, T-101-4, T-101-5, T-101-6, and T-125-2.

Kiamichi, Edwards and Comanche Peak formations. A road-metal quarry northwest of the highway at the scarp crest exposes the rudistid and caprinid-bearing white crystalline limestone of the Edwards. The Kiamichi is poorly exposed on the east side of the road at the crest and the Comanche Peak is well exposed in cuts along the road and in erosional promontories in the adjacent fields.

SOMERVELL COUNTY

Sta. T-101-1 (Fig. 10).—Walnut shell aggregate, roadside exposure 1.0 mile east of Nemo on the Glen Rose-Cleburne road (US 67-Texas 68).

Sta. T-101-2 (Fig. 10).—Walnut shell aggregate, roadside exposure 1.0 mile west of Nemo on the Glen Rose-Cleburne road (US 67-Texas 68).

Sta. T-101-3 (Fig. 10).—Glen Rose limestones and yellow marls in an exposure on the north side of the Glen Rose-Cleburne road at the northeastern boundary of Glen Rose city limits. Departing from Glen Rose, the ascending road curves southeast, then northwest at this locality, overlooks the bed of Paluxy Creek, and intersects with the Glen Rose-Granbury highway (Texas 144) 0.3 mile east. This locality is within the type area of the Glen Rose formation.

Sta. T-101-4 (Fig. 10).—Upper Glen Rose marls in roadside exposure of Glen Rose-Walnut Springs highway (Texas 144), 4.8 miles north of Somervell-Bosque county line or about 1.9 miles south of the Glen Rose courthouse. This exposure is within the upper 50 feet of the formation.

Sta. T-101-5 (Fig. 10).—Glen Rose limestones, dark clays and yellow marls exposed in the banks of Paluxy Creek near the eastern Glen Rose city

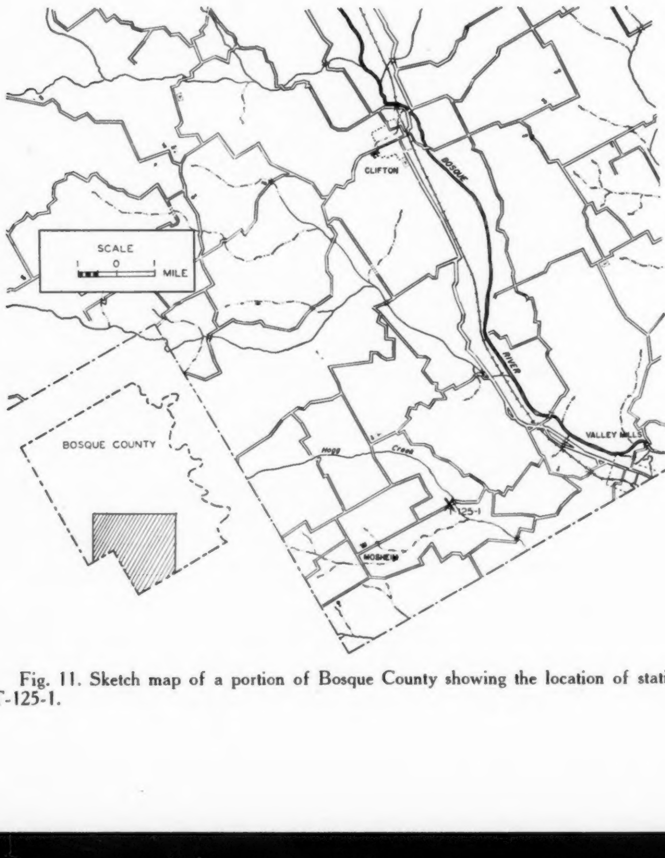

Fig. 11. Sketch map of a portion of Bosque County showing the location of station T-125-1.

limits at point where the Glen Rose-Stephenville road (US 67-Texas 68) crosses Paluxy Creek. The samples studied were collected just south of the concrete bridge and from the northern bank.

Sta. T-101-6 (Fig. 10).—Comanche Peak formation, roadside exposure of gray marls and white limestones about a mile northeast of the Somervell-Erath county line on the Glen Rose-Stephenville highway (US 67-Texas 68). This exposure is a cut through "Chalk Mountain," an excellent example of the Lampasas Cut Plain type of erosional remnant.

BOSQUE COUNTY

Sta. T-125-1 (Fig. 11).—Complete section of the Kiamichi formation composed of 14 feet of yellow clay-marls and thin white limestone ledges, overlain by massive *Desmoceras*-bearing Duck Creek limestone, exposed in roadside cut 2.6 miles northeast of Mosheim schoolhouse on the more northerly route from Mosheim to Valley Mills. The exposure is just west of the bridge over Hogg Creek, in the southern part of the county. This is the type

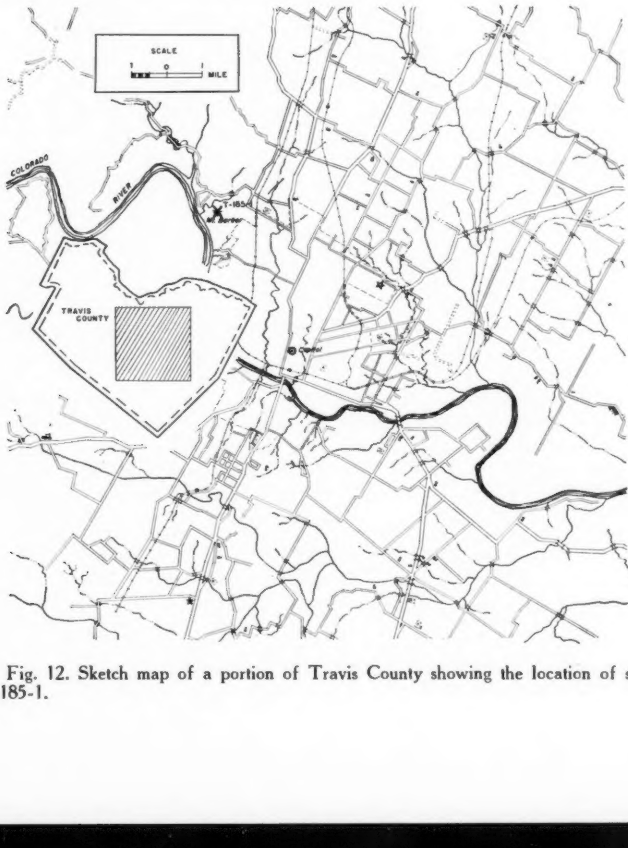

Fig. 12. Sketch map of a portion of Travis County showing the location of station T-185-1.

locality of *Lituola inflata*, n. sp., and the exposure from which hypotypes of *Frankeina acutocarinata* Alexander and Smith and *Placopsilina longa* Tappan were selected.

Sta. T-125-2 (Fig. 10).—Middle Comanche Peak limestones and marls are in roadside and creek bank exposures 2 miles south of the Somervell-Bosque county line on the Glen Rose-Walnut Springs highway (Texas 144). This locality is 4.3 miles north of the Walnut Springs depot.

TRAVIS COUNTY

Sta. T-185-1 (Fig. 12).—Upper Glen Rose, entire Walnut, and basal Comanche Peak in the road cuts through and hillside slopes of the south side of Mount Barker, about 3.5 miles (airline) northwest of the capitol building in Austin. This is the type locality for *Dictyoconus walnutensis* (Carsey) and *Coskinolina adkinsi* Barker. Paratypes of *Ammobaculites laevigata*, n. sp., are illustrated (Fig. 14) from this locality.

LOVE COUNTY, OKLAHOMA

Sta. O-43-1 (Fig. 13).—Paluxy (=Antlers) sandy clays in a high cliff on the east side of US 77, 3.4 miles north of the main road turning east from US 77 to Marietta, in the SE quarter, Sec. 31, T. 6S., R. 2E., Love County, Oklahoma. This is the type locality of *Ammobaculites subgoodlandensis, Reophax subgoodlandensis, Cytherelloidea subgoodlandensis, C. rhomboidalis* and *Cythereis subgoodlandensis* (Vanderpool, Jour. Pal. 7(4):406-511). Topotypes of *Ammobaculites subgoodlandensis* are figured in the text.

Paleontology

Introductory Statement

Ammonoids, echinoids, corals and pelecypods have long been used in the differentiation and zonation of north Texas Trinity and Fredericksburg deposits.

R. T. Hill's classical monograph (1901) not only summarized the pioneer works of Roemer, Marcou, Cragin, Shumard, and others, but contained a wealth of personal paleontologic and lithologic observation. It is to this work that later workers turn for the first broad but accurate résumé of formation differentiation in north Texas through the use of larger fossils.

The paleontologic studies of Adkins and Winton (1920) on the Fredericksburg and Washita formations of north Texas marked a distinct advance in the zonation of these deposits. These authors listed ten horizons and zones within the Walnut, Goodland, and Kiamichi formations.

Scott (1926) added a zonation of the Trinity group, revised the Fredericksburg zones of Adkins and Winton, and correlated this portion of the Texas section with the classic European column.

Adkins (1928) noted the stratigraphic position of known Trinity and Fredericksburg fossils in his supplement to and revision of Hill's checklist of Texas Cretaceous fossils.

Scott (1940a) lists five ammonite zones in the Trinity Group of the south-central United States, the upper two of these being present in North Texas. This author has a paper on Fredericksburg cephalopods in manuscript, but bryozoans, holothurian and echinodermal fragments, fish remains and charaphytes have yet to be studied.

Fig. 13. Sketch map of a portion of Love County, Oklahoma, showing the location of station O-43-1.

Papers on Trinity ostracodes by Vanderpool (1928a, 1928b, 1933) and on Fredericksburg ostracodes by Alexander (1929) provide the best zonation of these beds by microfossils that has been available. Papers on Foraminifera deal with species of isolated genera, are restricted geographically, or give occurrence lists in which several localities are grouped together. The most important of these contributions may now be reviewed:

Alexander (1928), using many outcrop samples, determined that *Flabellammina alexanderi* Cushman ranges from the upper one-third of the Goodland formation to the uppermost Kiamichi.

Cushman and Alexander (1930) gave stratigraphic-geographic observations on several species of *Vaginulina* present in Fredericksburg deposits.

Mrs. Plummer (1931), though concerned mainly with deposits above the Fredericksburg in central Texas, included several stratigraphic observations upon species represented in the north Texas Trinity and Fredericksburg. The same author (in Adkins 1932), also listed the occurrence of several foraminiferal species from one Kiamichi and three Goodland exposures in north Texas.

Alexander and Smith (1932) extended the ranges *Flabellammina alexananderi* Cushman and *Frankeina goodlandensis* Cushman and Alexander throughout the Washita formations of north Texas and their central and south Texas equivalents.

Lynch (1933) noted north and central Texas localities of Fredericksburg exposures from concentrates of which he observed "*Orbitolina*" *walnutensis* Carsey. He concluded with pertinent remarks on vertical range, horizontal distribution, and relationship of occurrence and size to the type of sediment containing the species.

It is my belief, after checking several of Lynch's localities and examining topotypes of the true "*Orbitolina*" *walnutensis* of Carsey collected in the company of Mrs. H. J. Plummer, that Lynch was referring to the small, elongate, triangular *Coskinolina adkinsi* Barker, present in the Goodland and Comanche Peak formations of north Texas. Carsey's species, to my knowledge, has not been reported from any other locality than the Mount Barker area, the type locality. I have not seen "*O.*" *walnutensis* in any north Texas concentrate.

Lalicker (1935) described two new species of *Spiroplectammina* from the Goodland formation and gave several localities from which these species had been observed.

Cushman's monographic studies (1937a, 1937b) of the *Verneuilinidae* and *Virgulininae* reviewed the occurrences of Texas Fredericksburg species of those groups.

Barker (1942) discussed some larger Foraminifera from the Texas Lower Cretaceous. His manuscript has been in my hands and I have drawn heavily upon his material in several instances.

The following annotated check list of north Texas Trinity and Fredericksburg Foraminifera includes critical notes on most species and systematic descriptions of those which are new. All figured specimens will be deposited in the Cushman Laboratory for Foraminiferal Research. Topotypes of new species will be deposited in the collections of Princeton University, the British Museum, the University of Texas Bureau of Economic Geology, the American Museum of Natural History, Leland Stanford Junior University, the University of Chicago and Texas Christian University.

Foraminiferal Descriptions and Critical Notes

Genus AMMOBACULITES Cushman, 1910

AMMOBACULITES GOODLANDENSIS Cushman and Alexander

Pl. 4, Fig. 4

Ammobaculites goodlandensis Cushman and Alexander, 1930, Contr. Cushman Lab. Foram. Res. **6**(1):8, pl. 2, figs. 7-8. (Goodland of north Texas).

Ammobaculites goodlandensis Cushman and Alexander, Tappan, 1940, Jour. Pal. **14**(2):96, pl. 14, figs. 8a-9. (Grayson of north Texas).

This species is typically composed of about 3 volutions forming an involute planispiral coil. The final whorl is composed of about 8 chambers. In sections through the plane of coiling about 8 chambers are revealed in the penultimate whorl with 5 or 6 in the remaining initial coiled portion. Sections and solution in hydrochloric acid reveal that the tectine[4] lining of the chambers varies markedly in extent among individuals from the same concentrate. Some specimens yield the complete, connected, bead-like lining of all chambers, others show only the lining for the inner initial coil, and some individuals lack this lining.

In the north Texas area this species is common to abundant in certain marl and clay-marl beds in the middle and upper thirds of the Goodland formation. I have not observed it in the dark shales of the Kiamichi north of Tarrant County, but it is present in the more marly facies of the formation in Bosque County. The species is apparently absent from the north Texas Walnut material examined. To the south, in the vicinity of Austin, *Ammobaculites goodlandensis* occurs commonly in the Walnut formation(Plummer, 1931, p. 122 and Thompson, 1935, p. 1527). In outcrop material of the Washita group in north Texas, the species is often abundant in the Grayson, frequent in the Denton, and present in the Duck Creek, Weno, and Main Street, but has not yet been observed in the Pawpaw or Fort Worth formations.

Hypotype (Cushman Coll. No. 36300) from the Goodland formation, station T-63-1, brown calcareous clay fifteen feet above the top of the Walnut shell aggregate.

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4 Tectine as a term for the albuminoid material forming all or a portion of the test of many Foraminifera is preferred rather than the commonly misused term "chitin" which is, in insects, a carbohydrate. See Moret, *Manuel de Paléontologie Animale*, Masson et Cie., Paris, 1940, footnote 1, p. 33.

Ammobaculites laevigata sp. nov.

Pl. 2, Figs. 2-3

Most north Texas specimens have a completely involute, close-coiled, biconvex test with the peripheral area broad, rounded and slightly lobate. These immature specimens are likely to be considered as belonging to the genus *Haplophragmoides*. About one-tenth of the central Texas specimens shows the rectilinear series with 1 to 3 chambers more compressed than those of the involute coil. The involute portion of the test is composed of numerous small chambers that appear triangular externally but which in section through the plane of coiling are quadrangular. The final volution of the majority of these involute specimens is made up of 9 to 10 chambers, the preceding coil has about 7, and the initial volution averages about 5 chambers. Chambers of the rectilinear series are rectangular in side view with their width slightly greater than twice their height. Sutures slightly depressed, clearly visible, and slightly curved posteriorly near the peripheral margin on the involute portion. In the rectilinear series, they are nearly straight and at right angles to the long axis of the series. The finely and uniformly granular wall is composed of very small siliceous particles with much calcareous cement. In thickness, the wall is about one fourth the chamber height. The aperture of involute individuals is a long slit in the long axis of the septal face beginning at the base of the face. In more mature individuals it occupies the center of the septal face.

Outline drawings (Fig. 14) of paratypes from the Walnut formation of central Texas, station T-185-1, illustrate typical variations in form and apertural position. In a progressive maturity series, the slit-like aperture tends to change its position from near the base of the septal face toward the center of that face. The degree of compression of the uncoiled portion, in rare specimens composed of 3 or 4 chambers, is not considered sufficient to place the form here discussed under Wiesner's genus *Ammomarginulina*.

This species has been found only in marls or clay-marls. In north Texas it occurs most commonly in lower Goodland concentrates and occasionally in the Walnut. In central Texas it is more abundant and is common in the Walnut and Glen Rose formations. It has not been observed in the Glen Rose material of north Texas.

Average diameter of holotype, 0.65 mm.; greatest thickness, 0.30 mm.; peripheral width, 0.15 mm.

Holotype and *paratype* (Cushman Coll. Nos. 36301 and 36302) from brown marl of the Goodland formation, station T-63-1, 15 feet above the top of the Walnut. *Paratypes* (Fig. 14, A-H, Cushman Coll. Nos. 36303-36310) from brown clays of the Walnut formation, station T-185-1, 12 feet below the base of the nodular white Comanche Peak limestones.

AMMOBACULITES SUBCRETACEUS Cushman and Alexander

Pl. 4, Figs. 2-3

Ammobaculites subcretacea Cushman and Alexander, 1930, Contr. Cushman Lab. Foram. Res. **6**(1):6, pl. 2, figs. 9-10. (Goodland of north Texas).

Ammobaculites subcretaceus Cushman and Alexander, Albritton, 1937, Jour. Pal. **11**(1):20, pl. 4, figs. 3-4. (Torcer, Malone Mountains of west Texas).

This species ranges throughout the Fredericksburg and probably into the Washita. In the concentrates examined it is abundant only at the type locality (Goodland formation, station T-85-8) and there at but one level about 50 to 55 feet below the base of the Kiamichi. Many specimens are broken and show only the coiled portion. Confusion of these portions with similar fragments of

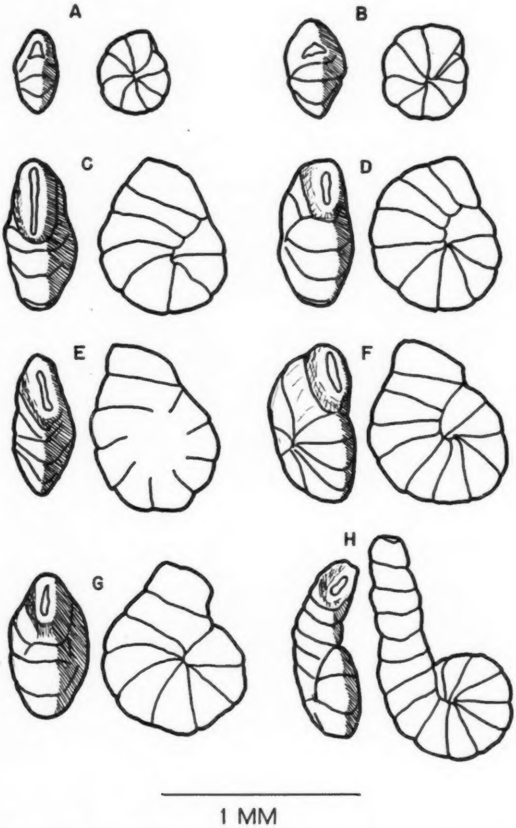

Fig. 14. Apertural and side views of paratypes (Cushman Coll. Nos. 36303-36310) of *Ammobaculites laevigata* sp. nov., illustrating position of aperture, variations in outline, and progression of chambers from immature involute forms resembling *Haplophragmoides* to those with at least one rectilinear chamber. The final specimen illustrated is considered aberrant.

immature individuals of *Spiroplectammina scotti* Cushman and Alexander may lead to inaccurate range determinations for both species.

Hypotypes (Cushman Coll. 36311 and 36312) from the type locality, Goodland formation, station T-85-8, blue marl 50 to 55 feet below the Goodland-Kiamichi contact.

AMMOBACULITES SUBGOODLANDENSIS Vanderpool

Pl. 1, Figs 2-3; Pl. 4, Fig. 1

Ammobaculites subgoodlandensis Vanderpool, 1933, Jour. Pal. **7**(4):407, pl. 49, figs. 1-3. (Antlers fm. of southern Oklahoma).

This large, thick-walled, coarsely arenaceous species with collapsed chambers was described from sub-Goodland sandy clays near Marietta, Oklahoma. Numerous topotypes show variation in width of the uncoiled portion but a consistent plan for the coiled chambers (Fig. 15). The planispiral portion

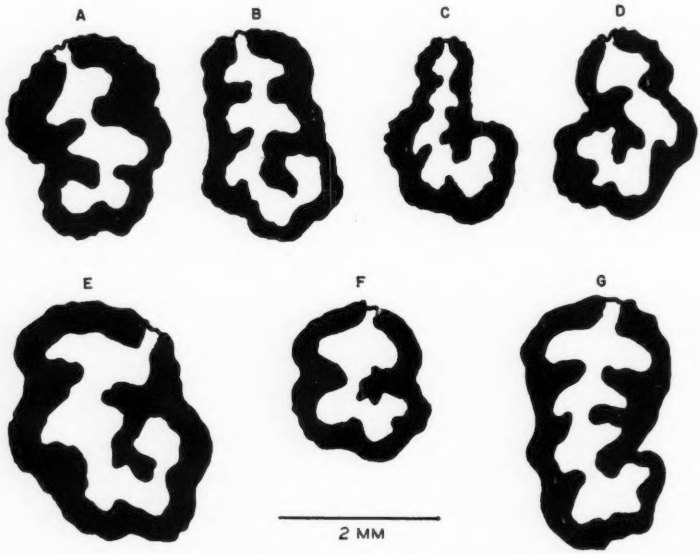

Fig. 15. Camera lucida drawings of topotypes (Cushman Coll. Nos. 36316-36322) of *Ammobaculites subgoodlandensis* Vanderpool. The outer margin of the black portion of each sketch represents the peripheral margin and illustrates configuration and size variations among the individuals. The white portion within each sketch represents the chamber arrangements, shapes, and interconnections as inferred from the observed collapsed areas of the test when viewed externally. The solid black represents the wall material surrounding the chambers. These sketches were not prepared from thin-sections although such sections were used interpreting the external features.

consists of 4 or 5 chambers and averages 1.5 mm. in diameter. The rectilinear portion is made up of 1 to 3 chambers.

Specimens from Walnut and Goodland concentrates differ from topotypes primarily in texture, relative and absolute size of sand particles and amount of cement. The north Texas Walnut specimens have particles of the same texture as the topotypes but possess a slightly greater amount of cement. The Goodland individuals have an even greater amount of cement with the particles so small that the finish is relatively smooth.

Cited occurrences of this species in Love County, Oklahoma, Cooke County, Texas (Thompson, 1935, p. 1516) and observed occurrences in Wise and Tarrant counties, Texas, indicate that this widespread species is more common in argillaceous deposits with an appreciable amount of quartz sand. The occurrences in the Goodland marls reflect this sand absence in the more smoothly finished tests.

Hypotypes (Cushman Coll. Nos. 36313 and 36314) from the Walnut formation, station T-64-5, are from blue shelly clay-marl 10 feet above the base of the formation. *Hypotype* (Cushman Coll. No. 36315) from the Goodland formation, station T-85-16, is from blue and brown marl within the basal 12 feet. *Hypotypes* (Fig. 15 A-G, Cushman Coll. Nos. 36316-36322) from the Antlers sandy clay, station O-43-1, immediately below the base of the Goodland limestone.

Genus FLABELLAMMINA Cushman, 1928

FLABELLAMMINA ALEXANDERI Cushman

Pl. 4, Figs. 15-16

Flabellammina alexanderi Cushman, 1928, Contr. Cushman Lab. Foram. Res. **4**(1):1, pl. 1, figs. 3-4. (Goodland of north Texas).

Flabellammina alexanderi Cushman, Alexander and Smith, 1932, Jour. Pal., **6**(4):300, pl. 45, figs. 1-5, 15. (Goodland and Denton of north Texas; Del Rio of south Texas).

Flabellammina alexanderi is the most variable in outline, most common in occurrence, and exhibits the greatest stratigraphic range of the Texas Comanchean representatives[5] of the genus. Megalospheric specimens are lanceolate and narrow, microspheric individuals are spatulate to ovate and occasionally almost circular in outline.

The species ranges throughout the Fredericksburg and Washita groups. An abundant occurrence of the species is usually indicative of Fredericksburg material, but several Washita concentrates from the Fort Worth and Grayson formations have also proved rich in quantity of individuals.

Excepting the facies rich in quartz sands, this species shows no preference between calcareous and argillaceous deposits. Though most of the Goodland

5 Others described species, all confined to the Washita, are *F. longiuscula* Alexander and Smith, *F. rugosa* Alexander and Smith, and *F. washitensis* Alexander and Smith.

material examined is marly, the species is often equally abundant in the clays of the Walnut, Kiamichi, Denton and Grayson as well as the more calcareous facies of these formations.

Hypotypes (Cushman Coll. Nos. 36323 and 36324) are from the Kiamichi formation, station T-85-2, from brownish clay near the top of the exposure in the upper part of the formation.

Genus FRANKEINA Cushman and Alexander, 1929

FRANKEINA ACUTOCARINATA Alexander and Smith

Pl. 1, Fig. 7

Frankeina acutocarinata Alexander and Smith, 1932, Jour. Pal. **6**(4):307, pl. 47, figs. 1, 6. (Duck Creek and Fort Worth of north Texas).

This large, distinctly carinate species is common to abundant in almost all Duck Creek and Fort Worth and in many Denton concentrates from north Texas. The softer portions of the Duck Creek and Fort Worth are always marly and there are many marly levels within the Denton. The species apparently thrived under the set of physical conditions resulting in that type of sediment. One Kiamichi locality, station T-125-1, has furnished a number of individuals of this species. It is not surprising, because this exposure is the most marly of all the Kiamichi localities from which collections were made.

Hypotype (Cushman Coll. No. 36325) from the Kiamichi formation, yellow clay-marls one foot below the Kiamichi-Duck Creek contact, station T-125-1.

FRANKEINA GOODLANDENSIS Cushman and Alexander

Pl. 3, Fig. 8

Frankeina goodlandensis Cushman and Alexander, 1929, Contr. Cushman Lab. Foram. Res. **5**(3):62, pl. 10, figs. 1-2. (Goodland of north Texas).

Frankeina goodlandensis Cushman and Alexander, Alexander and Smith, 1932, Jour. Pal. **6**(4):307, pl. 47, fig. 8. (Goodland of north Texas).

This species is small, tapering, smoothly finished, and occasionally twisted slightly on its long axis. Occurrence of the species in any great quantity is indicative of the Goodland formation, particularly the upper half. The species is rare in concentrates from several Kiamichi localities and occasional specimens referable to this species have been found in Duck Creek and Fort Worth material.

Frankeina goodlandensis is most commonly found in dominantly calcareous deposits with a minor proportion of argillaceous material present. It has not been observed in quartzose sands or true clays.

Hypotype (Cushman Coll. No. 36326) from the Goodland formation, station T-85-13, blue marl near road level, within the upper 25 feet of the formation.

Genus HAPLOPHRAGMOIDES Cushman, 1910

Haplophragmoides globosa sp. nov.

Pl. 2, Figs. 8 a-c

Test very small, closely coiled, often very slightly trochiform in appearance; it has a round and broad periphery. The chambers are numerous, about 10 in the final volution, and are small and bluntly triangular in sections through the place of coiling. The final 2 or 3 sutures are slightly depressed and curved; those between the older chambers are usually indistinct and visible only on moistened specimens. The comparatively thick wall is composed of moderately-coarse sand grains with very little calcareous cement. These grains produce a beadlike and irregular exterior. The indistinct aperture is apparently an arched slit at the base of the apertural face.

Diameter of holotype 0.25 mm.; thickness through the umbilical area 0.15 mm.

This small species has been noticed only in upper Goodland marly material and seems to be well represented geographically within Tarrant County. The slightly trochoid appearance is not enough to place this species under the genus *Trochammina*. An examination of 35 random specimens from one Goodland concentrate, station T-85-13, showed no consistency in direction of trochiform coiling. In 7 specimens the final chamber overlaps farther on the

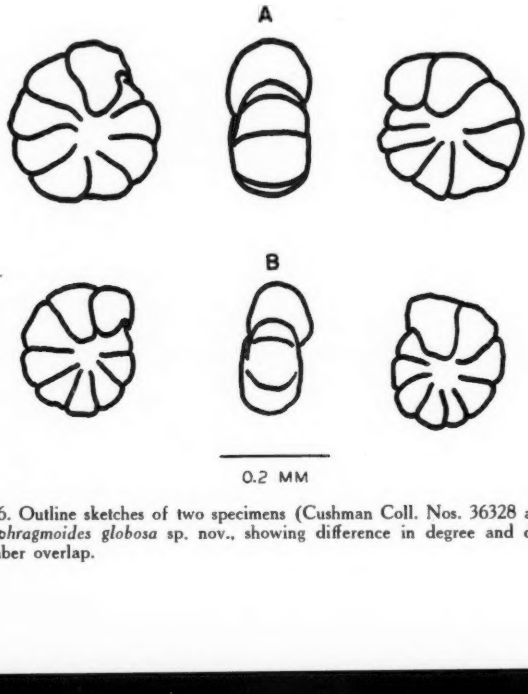

Fig. 16. Outline sketches of two specimens (Cushman Coll. Nos. 36328 and 36329) of *Haplophragmoides globosa* sp. nov., showing difference in degree and direction of final chamber overlap.

left flank, with the specimen mounted on the periphery to show the apertural face. It overlaps on the right flank in 8 specimens, there is apparently no difference in degree of overlap on 14, and 6 specimens are too incomplete or too obscure for determination. Camera lucida sketches (Fig. 16) show the overlap variation of two typical specimens chosen as paratypes.

Holotype (Cushman Coll. 36327) from the Goodland formation, station T-85-8, from blue marl between thin white limestone ledges 16 feet below the base of the Kiamichi. *Paratypes* (Cushman Coll. Nos. 36328 and 36329) (Fig. 16, A-B) from upper Goodland dark marls, station T-85-13.

Haplophragmoides trinitensis sp. nov.

Pl. 1, Figs. 8a-b

Test large, stout and involute; umbilical area noticeably depressed. The ovoid peripheral area increases in breadth toward the aperture and is notched by sutural indentations. There are 3 volutions and about 18 chambers in the average specimen, the final volution containing 7 to 10 chambers. The depressed sutures are usually straight, occasionally slightly curved posteriorly. Wall moderately rough with variable relief caused by differing size of the fragments and because the calcareous cement does not entirely surround many of the particles. The triangular to ovate aperture is rather small and located in a slight depression at the base of the apertural face.

Diameter of holotype, 0.80-0.85 mm.; greatest thickness, 0.30 mm.

Haplophragmoides trinitensis resembles immature specimens of *Ammobaculites goodlandensis* Cushman and Alexander in size and general appearance, but lacks the broad, truncate periphery and nodose, laterally overhanging chambers of the latter species.

This species, at the present time, is known only from Glen Rose material. It has been observed only in yellow or brown marls and sandy clays and ranges from central to north Texas.

Holotype (Cushman Coll. 36330) from the Glen Rose formation, station T-84-1, from brown sandy clays about 6 feet above the *Orbitolina concava texana* (Roemer) zone near the middle of the formation.

Genus LITUOLA Lamarck, 1804

Lituola camerata sp. nov.

Pl. 1, Figs. 4-5

Test fairly large, its planispiral portion composed of 5 to 7 rather elongate ovoid chambers. Of these chambers, only the later 3 or 4 are visible externally. Median sections through the plane of coiling of several specimens (Fig. 17) reveal that in addition to the proloculus, 1 to 4 chambers are hidden from external view. Foramina between these chambers apparently are small, circular and located near the bases of the septa. The rectilinear portion is, in

mature specimens, composed of 2 or more bluntly conical chambers of which the height is slightly greater than the maximum diameter. The relatively thick wall is composed of medium-sized, clear sands with a considerable amount of calcareous and limonitic cement. The external surface is rather smoothly finished. The foramen connecting the initial rectilinear chamber with the final chamber of the coiled portion is usually single, circular and terminal. Immature specimens with but one rectilinear chamber are apt to have this same type of opening for an aperture. In mature specimens with 2 or more rectilinear chambers, the aperture is cribrate and located on the terminus of a small neck-like extension.

Diameter of planispiral portion of holotype, 0.7 to 1.0 mm.; total length, 2.3 mm.

Lituola camerata, sp. nov., has been observed as a rare form in central Texas Walnut clays and commonly in north Texas Goodland marls. The species is rather easily distinguished from *Lituola inflata* sp. nov. by its characteristic cone-shaped rectilinear chambers. Although much larger and fewer in number, the planispiral chambers of *Lituola camerata* resemble closely those of the coiled portion of *Ammobaculites goodlandensis* Cushman and Alexander and these may be related. Common or abundant occurrences of the former

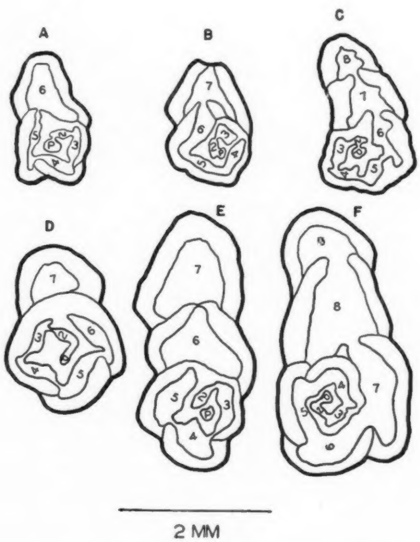

Fig. 17. Camera lucida sketches of median sections through the plane of coiling of specimens (Cushman Coll. Nos. 36333-36338) of *Lituola camerata*, sp. nov. Specimens B and C are from the Goodland formation, station T-84-7. The remainder are topotypes.

species generally are accompanied by great numbers of the latter, though the reverse is not always true.

Holotype (Cushman Coll. No. 36331) from the Goodland formation, station T-85-8, blue marl within and near the middle of a 13-foot chalky limestone bed about 42 feet below the top of the formation; *paratype* (Cushman Coll. No. 36332) from the upper portion of the Goodland formation, station T-85-15, gray-brown marl 3 feet thick.

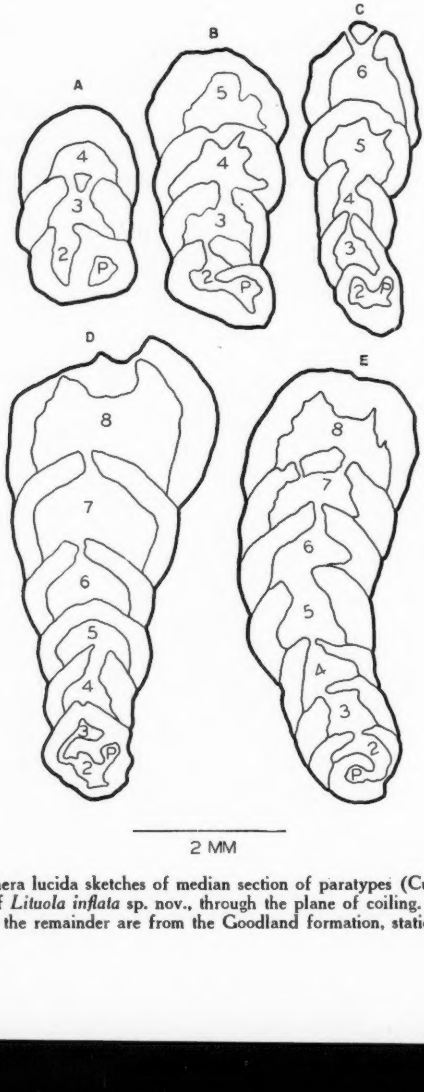

Fig. 18. Camera lucida sketches of median section of paratypes (Cushman Coll. Nos. 36340-36344) of *Lituola inflata* sp. nov., through the plane of coiling. Specimens B and C are topotypes, the remainder are from the Goodland formation, station T-84-7.

Lituola inflata sp. nov.

Pl. 1, Figs. 1a-b

Test large, rather coarsely arenaceous; its planispiral portion is composed of a single volution with 2 or 3 globular chambers clearly seen in sections (Fig. 18) and faintly defined externally by sutures. Increasing rapidly in diameter as the rectilinear portion is approached, these chambers are not so clearly defined by sutural depressions as are the later rectilinear or occasionally curvilinear chambers which make up the greater portion of the test. These later chambers are inflated and globular except in individuals that have apparently undergone compression or distortion after burial. With the exception of the final, and occasionally the penultimate chamber, each chamber in the rectilinear portion overlaps the preceding one about one third to one half of the total chamber height. The rectilinear series of 2 to 4 or more chambers occasionally deviates from the usual straight linear arrangement to a slight curve continuing in the direction of coiling of the planispiral portion. The thick wall is composed of fine to medium sized quartz grains and other clastics cemented by a considerable amount of calcareous material into a usually smooth and occasionally coarse external finish. Foramina are simple in the early portion and become terminal and cribrate in the later chambers. The aperture is definitely cribrate and consists of several closely spaced angular openings.

Length of holotype, 5.3 mm.; greatest width of final chamber, 1.5 mm.; greatest height of final chamber, 1.6 mm.

Lituola inflata occurs in the marls of the Glen Rose, the marly clays of the Walnut, the Goodland marls, and the more marly Kiamichi clays. Quartz sand is often present in the Glen Rose and Walnut concentrates but in dominantly sandy residues the species has not been observed. It is not represented in my north Texas Washita material.

This species may be confused with *Lituola edwardsensis* Ikins and Clabaugh (1940, p. 267) from the Edwards formation of central Texas. Through the courtesy of these authors, I have been able to examine a few topotypes. All of these specimens are much longer and more irregular in the later chamber arrangement than any individual of *Lituola inflata* that I have seen.

This species was erroneously considered as *Haplostiche texana* (Conrad) for at least one pre-Washita occurrence mentioned in the literature. In the company of W. M. Winton, who discovered the specimens in 1919, and Gayle Scott, who referred these Goodland forms (1926, p. 48) to *Nodosaria texana* Conrad [=*Haplostiche texana* (Conrad)], I have re-collected the exact locality, station T-84-7. All unbroken specimens that have the earliest chambers definitely have the initial 2 chambers in a planispiral arrangement. Surficially, the weathered specimens resemble microspheric individuals of *Haplostiche texana* very closely, but median section through the plane of coiling of both species leave no doubt as to their generic differences. (Compare Fig. 18 and Fig. 19). Other Trinity (Adkins, 1927, p. 27; Plummer, 1931, p. 125) and Fredericksburg (Plummer, 1931, p. 126, footnote 8) occurrences

of *Haplostiche texana* are doubted, but actual specimens have not been in my hands for verification. In my Washita mounts, *Haplostiche texana* is represented in but one Duck Creek sample, is absent from the Fort Worth, abundant in the Denton and often is common in the remaining formations. The species is apparently most common in marls.

Holotype (Cushman Coll. No. 36339) from yellow clay-marls between thin white limestone ledges within the Kiamichi formation about 6 feet above the top of the Edwards, station T-125-1.

Genus SPIROPLECTAMMINA Cushman, 1927

SPIROPLECTAMMINA ALEXANDERI Lalicker

Pl. 4, Fig. 6

Spiroplectammina alexanderi Lalicker, 1935, Contr. Cushman Lab. Foram. Res. **11**(1):1, pl. 1, figs. 1a-c. (Goodland of north Texas).

This very small species is distinguished easily from other Comanchean species by its nearly parallel sides, as well as its size and circular top view. With the exception of a few specimens from one Walnut and one Duck Creek locality, it is restricted to the Goodland with abundant occurrences characteristic of the soft marls of the middle and upper thirds of the formation. It may

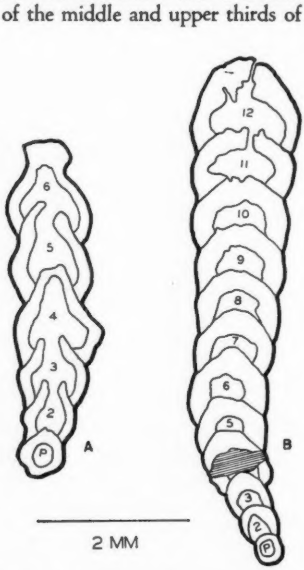

Fig. 19 Camera lucida sketches of longitudinal median sections of *Haplostiche texana* (Conrad). Specimen A is a mature megalospheric individual, B is a mature microspheric specimen. Both specimens (Cushman Coll. Ncs. 36345 and 36346) are from the Pawpaw formation, station T-85-4.

thus be used as an index fossil for that portion of the Fredericksburg group in north Texas.

Hypotype (Cushman Coll. No. 36347) from the Goodland formation, station T-85-7, from blue marl just beneath *Oxytropidoceras acutocarinatum* (Shumard) limestone ledge within the upper portion of the formation.

Spiroplectammina goodlandana Lalicker

Pl. 4, Fig. 5

Spiroplectammina goodlandana Lalicker, 1935, Contr. Cushman Lab. Foram. Res. **11**(1):2, pl. 1, figs. 2-3. (Goodland of north Texas).

This species is slightly larger than *S. alexanderi* Lalicker and is distinguished by the pronounced compression of the later chambers. Superficially resembling *S. longa* Lalicker, a widespread and long ranging species occurring in every formation of the Washita group, it differs in having sutures more nearly horizontal, and in flatter and less inflated chambers.

Reported to be very common at one Denton County locality, this species is sparsely represented elsewhere and has been observed only in concentrates of marls from station T-85-8. It appears to be restricted to the upper middle portion of the Goodland formation but its limited geographic range reduces its value as an index fossil.

Hypotype (Cushman Coll. No. 36348) from the Goodland formation, station T-85-8, from blue marl about 55 feet below the top of the formation.

Spiroplectammina scotti Cushman and Alexander

Pl. 3, Fig. 1

Spiroplectammina scotti Cushman and Alexander, 1930, Contr. Cushman Lab. Foram. Res. **6**(1):8, pl. 2, figs. 11a-b. (Goodland of north Texas).

Most specimens representing this species are broken and show only the close-coiled early portion. The fragments are distinct, however, and differ from *S. whitneyi* Cushman and Alexander primarily in their greater size. Similarly, fragments of *S. scotti* Cushman and Alexander showing only the early coil may be confused with fragments of *Ammobaculites subcretaceus* Cushman and Alexander but again the planispiral portion of the former is larger. Moreover, the chambers of this species nearly always have a deflated, sunken appearance.

S. scotti Cushman and Alexander seems to have a great areal and vertical range. Tentatively basing some identifications on the coiled fragment only, this species is apparently represented at differing levels in all Fredericksburg formations, and in several Denton, Weno and Grayson concentrates. Its variable occurrence at different levels and from marls, clays and sandy clays is similar to that of *Ammobaculites goodlandensis* Cushman and Alexander.

Hypotype (Cushman Coll. No. 36349) from the Kiamichi formation, station T-85-2, from blue-black sandy clay in the lower portion of the formation.

Genus VERNEUILINA d'Orbigny, 1840

VERNEUILINA SCHIZEA Cushman and Alexander

Pl. 3, Fig. 6

Verneuilina schizea Cushman and Alexander, 1930, Contr. Cushman Lab. Foram. Res. **6**(1):9, pl. 2, figs. 13-14. (Goodland of north Texas).

Verneuilina schizea Cushman and Alexander, Cushman, 1933, Special Publ. **5**, Cushman Lab. Foram. Res.; pl. 7, figs. 21a-b. (Goodland of north Texas).

Verneuilina schizea Cushman and Alexander, Cushman, 1937, Special Publ. **7**, Cushman Lab. Foram. Res.: 8, pl. 1, figs. 5-6. (Goodland of north Texas).

Previously recorded in the north Texas area only from the Goodland formation, I have found this sole Comanchean representative of the genus to be common in several Walnut concentrates.[6] *V. schizea* Cushman and Alexander is apparently confined to the Fredericksburg group, and for the present may serve as an index of the lower and middle formations of the group.

Solution of topotypes in hydrochloric acid leaves little or no residue. Any residue present may be from the internal filling or later attached insoluble grains after burial of the test. The test does not appear more arenaceous than many Lenticulinas, for example, that have had their originally hyaline test altered by burial and weathering. Further study may show that the test of this species was originally hyaline, rather than finely arenaceous and agglutinated with a considerable proportion of calcareous cement.

This species is often abundant in marls and clay-marls. In quartz-bearing deposits it is rare or absent.

Hypotype (Cushman Coll. No. 36352) from the Walnut formation, station T-64-5, from the blue shelly marl 10 feet above the base of the formation.

Genus COSKINOLINA Stache, 1875

COSKINOLINA ADKINSI Barker[7]

Pl. 5, Figs. 3-6

In north Texas *C. adkinsi* has been observed abundantly in Comanche Peak marls from stations T-99-3 and T-101-6 and less commonly in a few concentrates from the Goodland formation. In central Texas (station T-185-1) the species is very common in the Walnut clays and overlying Comanche Peak marls.

This small, conical, trochiform species has been carefully examined by R. Wright Barker and the following statements are from his personal communication of March 9, 1941:

> This species shows the typical structure of *Coskinolina* as demonstrated by Colonel Davies (1930) but differs from all species previously described in its much smaller size

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6 This species has been recognized by H. J. Plummer (Univ. of Texas Bull. **3232**:333) in the Walnut of central Texas.

7 See footnotes and remarks under *Orbitolina concava texana* (Roemer).

and more primitive character. So far as is known it is the oldest recorded species of *Coskinolina*. . . . [and] is the first species to be described from beds of Mesozoic age.

It is highly probable that this form was confused with *Dictyoconus walnutensis* (Carsey) by Lynch (1933), who has recorded '*Orbitolina walnutensis*' from numerous localities in the Fort Worth region.

Samples from this region of the Comanche Peak and Goodland formations contained numerous small conical tests, of considerably smaller size than *D. walnutensis*, though resembling that species superficially. Sections showed these forms to possess the characters of *Coskinolina* rather than *Dictyoconus*, and the species has been named *Coskinolina adkinsi*.

SPIROPLECTAMMINA cf. WHITNEYI Cushman and Alexander

Spiroplectammina whitneyi Cushman and Alexander, 1930, Contr. Cushman Lab. Foram. Res. **6**(1):8, pl. 2, figs. 12a-b. (Goodland of north Texas).

This very small species is characterized by a braided appearance of the biserial portion. It is reported to be common in basal Goodland material but in no basal Goodland concentrates in my material has the species been recognized. The Kiamichi occurrence is restricted to one sample from one locality, and the specimens are much more compressed than the holotype. If these Kiamichi specimens are conspecific with the holotype, the compression must be attributed to physical factors such as method of preservation rather than to biologic factors.

Genus TEXTULARIA Defrance, 1824

TEXTULARIA RIOENSIS Carsey

Pl. 3, Figs. 7, 9a-b

Textularia sp., Margaret Carpenter, 1925, Univ. Texas Bull. **2544**, pl. 17, fig. 15. (Upper Washita of north Texas).

Not *Textularia conica* d'Orbigny, Carsey, 1926, Univ. Texas Bull. **2612**:23, pl. 7, fig. 1. (Del Rio of central Texas).

Textularia rioensis Carsey, 1926, Univ. Texas Bull. **2612**:24, pl. 7, fig. 2. (Del Rio of central Texas).

Textularia rioensis Carsey, Plummer, 1931, Univ. Texas Bull. **3101**:128, pl. 8, fig. 6. (Del Rio of central Texas).

Textularia rioensis Carsey, Tappan, 1940, Jour. Pal. **14**(2):98, pl. 14, figs. 1a-2b. (Grayson of north Texas).

The typical elongate form of *Textularia rioensis* Carsey ranges throughout the Fredericksburg and Washita groups. Occurring with the elongate specimens, but more commonly in lower Fredericksburg samples, are compressed forms differing in several features from the typical examples. These compressed specimens, called *T. conica* by Carsey, are shorter and broader, and have the apertural chamber noticeably depressed along the long axis of the apertural view. It is possible that this sharply expanding, nearly equilateral type should be assigned a varietal rank.

In Fredericksburg material, this species is most common in marls. In the Washita, it is often abundant in clays and sandy clays in addition to marls.

Hypotype (Cushman Coll. No. 36350) from the Goodland formation, station T-85-8, from blue marl about 58 feet below the base of the Kiamichi. *Hypotype* (Cushman Coll. No. 36351), the compressed variety, from the Walnut formation, station T-64-5, from blue shelly marl 17 feet above the Paluxy sand.

Genus TROCHAMMINA Parker and Jones, 1859

Trochammina depressa sp. nov.

Pl. 2, Figs. 4a-b, 5

Test small, trochoid compressed and collapsed; the dorsal side more convex than the ventral, and the acute periphery is lobulate. Average specimens are composed of about 10 chambers equally divided between inner and outer whorls. These chambers increase in size toward the final chamber. Dorsal sutures are curved posteriorly and appear elevated because of the deflated chambers. Ventral sutures are radiate and almost straight. The thin wall is finely arenaceous and composed of subangular quartz grains with non-calcareous cement. The obscure aperture is apparently an arched slit at the inner margin of the ventral side of the final chamber.

Greatest diameter of holotype, 0.27 mm.; average thickness, 0.02 mm.

This fragile species has been observed in lower Kiamichi concentrates from 3 widely separated localities. It is very abundant in the basal material at the paratype locality. This species is one of the few that is found in dark, blue or black carbonaceous shales. It has not been found in the lighter-colored, more marly portion of the Kiamichi.

Holotype (Cushman Coll. No. 36353) from black carbonaceous fissile shale 4 feet above the top of the Goodland limestone, station T-48-2. *Paratype* (Cushman Coll. No. 36354) from basal portion of the Kiamichi formation, station T-85-2, dark clay between uppermost white Goodland limestone and lowest sandy limestone ledge of the Kiamichi.

Genus PLACOPSILINA d'Orbigny, 1850

PLACOPSILINA LONGA Tappan

Pl. 3, Fig. 3

Placopsilina longa Tappan, 1940, Jour. Pal. **14**(2):100, pl. 15, figs. 9a-10. (Grayson of north Texas).

Placopsilina longa Tappan is a large, wholly or partially attached, multichambered, arenaceous species with variable outline and degree of coiling. Some of these and additional variations are shown in Fig. 20. Fragments of the uncoiled portion that were not attached resemble the rectilinear portions of *Bigenerina wintoni* Cushman and Alexander but differ from the latter in being much greater (twice or more) in diameter. What appears to be an umbilical plug of solid material in some specimens is in reality the outer covering of the proloculus. This chamber protrudes above the coil in most specimens; the wall is usually broken so that a rimmed depression marks the location, but this chamber does not appear as a plug on all specimens.

Though most abundant in Duck Creek and Fort Worth marls, this species has been found in all Washita formations. In my Fredericksburg samples, it is fairly common only in those from the marly facies of the Kiamichi.

Hypotype (Cushman Coll. 36355) from the Kiamichi yellow clay-marls between thin white limestone ledges about 6 feet above the Edwards, station T-125-1.

Genus ORBITOLINA d'Orbigny, 1850

ORBITOLINA CONCAVA TEXANA (Roemer)

Pl. 5, Figs. 1-2

R. Wright Barker[8] has prepared a detailed discussion of this subspecies and its synonymy, as well as descriptions and discussions of *Coskinolina adkinsi* and *Dictyoconus walnutensis*, two larger Foraminifera from the Lower Cretaceous of Texas. Concerning the subspecies *texana* Barker concludes:

> *Orbitolina texana* seems to be almost identical with the European *O. concava* (Lamarck) [described as Orbitolites in 1801], as revealed by a study of available figures and descriptions, but, in the absence of comparative material, it would be rash

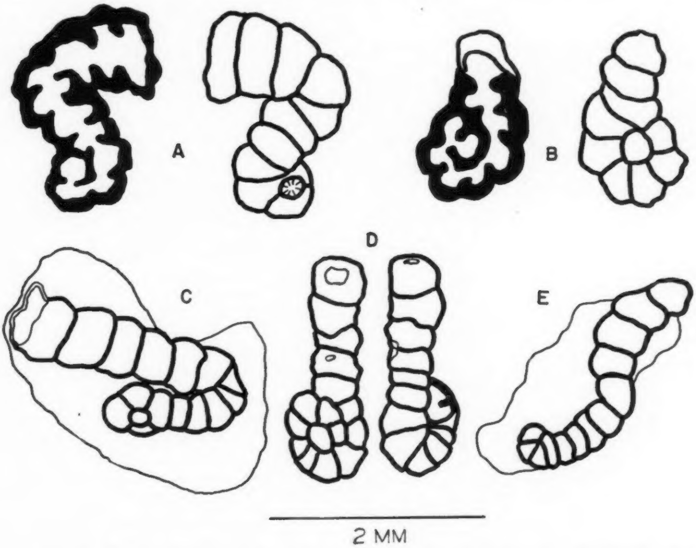

Fig. 20. Camera lucida sketches of variant individuals (Cushman Coll. Nos. 36356-36360) of *Placopsilina longa* Tappan from one Pawpaw concentrate, station T-85-4.

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8 Abstract in Am. Assoc. Petroleum Geologists. Program of 27th Ann. Convention, Denver, April 1942, p. 50. The manuscript has since been published in the Journal of Paleontology (see addenda).

to regard them as synonymous. Silvestri had abundant material of both species and decided that *texana* should be classed as a variety of *O. concava* (Lamarck), a conclusion which, coming from such a careful worker, would appear to be final. However, since typical *O. concava* has not been reported from the Americas and *O. texana* is not known from the Old World it would seem preferable to consider the Texas form as a geographic variant or subspecies of *O. concava* rather than as a true variety (occurring with the type), so that the nomenclature would be *Orbitolina concava texana* (Roemer).

The north Texas specimens are somewhat smaller than those usually found in the neighborhood of Austin, and are generally less depressed, with a more convex base, the central depression being entirely lacking in some specimens.

This widespread Albian, and perhaps Aptian, foraminifer has been observed at only one Glen Rose outcrop, station T-84-1, in the area under discussion. Another *Orbitolina*-bearing seam about 50 feet below the Sanchez Creek horizon is reported by Scott (1930, p. 43) but as yet I have not collected from this locality (about 2.5 miles northeast of Dennis, Parker County). Ordinarily considered indicative of the Glen Rose formation, this species has been found by Cuyler (1939, p. 637) in the Hensell sand, the topmost member of the Travis Peak formation in central Texas, and by Mrs. H. J. Plummer[9] in the Walnut formation as exposed on Mount Barker near Austin, Travis County.

Occurrences of *O. concava texana* known or reported to me are limited to marly sands, sandy and marly limestones, and marly clays. It is probable that physical factors not revealed by lithologic facies alone are responsible for the biostratigraphic distribution of this species. By means of associated macrofossils, the species is believed to have favored a rather clean bottom habitat in very shallow water.

Genus DENTALINA d'Orbigny, 1826

DENTALINA COMMUNIS d'Orbigny

Pl. 4, Fig. 9

Nodosaria (Dentalina) communis d'Orbigny, 1826, Annals des Sci. Nat. Hist. **7**:254, no. 35. (Recent, Adriatic Sea).

Nodosaria communis d'Orbigny, Carsey, 1926, Univ. Texas Bull. **2612**:34, pl. 7, fig. 3. (Del Rio of central Texas).

Dentalina communis d'Orbigny, Plummer, 1931, Univ. Texas Bull. **3101**:149, pl. 11, fig. 4, (Del Rio of central Texas).

Dentlina communis d'Orbigny, Eichenberg, 1933, Niedersächs. geol. Ver. Jahresber. Folge 2, **25**:185, pl. 19, fig. 3; pl. 21, fig. 7. (Barremian of Germany), 1935, Roemer-Mus., Mitteil., Folge 4, **37**:19, pl. 1, fig. 24. (Aptian of Germany).

Dentalina communis d'Orbigny, Tappan, 1940, Jour. Pal. **14**(2):102, pl. 16, fig. 1. (Grayson of north Texas).

This smooth, undecorated species has been recorded by many authors from Cretaceous to Recent, and but a limited synonymy of several Lower Cretaceous

9 Personal communications, dated January 2 and 8, 1941.

designations is given here. Specimens here assigned to this species have been noticed in brown Kiamichi clays and Goodland marls. Most of the individuals have a bulbous proloculus and are probably megalospheric forms.

Hypotype (Cushman Coll. No. 36361) from the Goodland formation, station T-85-8, blue marl 55 feet below the base of the Kiamichi.

DENTALINA DEBILIS (Berthelin)

Pl. 4, Fig. 17

Marginulina debilis Berthelin, 1880, Soc. géol. France, Mém., sér. 3, **1**(5):35, pl. 3, fig. 28. (Albian of France).

Marginulina debilis Berthelin, Chapman, 1894, Roy. Micr. Soc., Jour.: 161, pl. 4, fig. 15. (Gault of Folkestone, England).

Marginulina debilis Berthelin, Egger, 1910, Nat. Ver. Regensburg, Bericht: 109, pl. 1, fig. 16. (Cretaceous of Europe).

Dentalina debilis (Berthelin), Eichenberg, 1933, Niedersächs. geol. Ver., Jahresber. Folge 2, **25**:183, pl. 23, fig. 10. (Barremian of Germany), 1934, Niedersächs. geol. Ver., Jahresber. Folge 3, **26**:167, pl. 12, fig. 9. (Hauterivian of Germany).

Vaginulina debilis (Berthelin), Tappan, 1940, Jour. Pal. **14**(2):108, pl. 16, figs. 26a-b. (Grayson of north Texas).

This species, well developed in the Washita group, is represented sparingly in the Goodland formation of the north Texas Fredericksburg. Complete tests of this delicate form are rare, but the deeply indented ventral margin and neck-like elongation of the apertural chamber are distinctive. The figured specimen is broken and lacks the initial 3 or 4 smaller chambers.

In the Washita group, the species is most common in clays, present in marls, and absent from quartzose material.

Hypotype (Cushman Coll. No. 36362) from dark marls of the upper portion of the Goodland formation, station T-85-13.

Genus ASTACOLUS Montfort, 1808

Astacolus comanchensis sp. nov.

Pl. 2, Figs. 1a-b

Test partially evolute and slightly elongate, with a thin keel and an even peripheral margin. Typical specimens have 10 to 15 uninflated chambers. The earlier chambers of the tightly coiled portion of the test radiate away from the central boss; later chambers of more mature forms tend to become uncoiled. Rare tests show actual departure of the final chambers from the coil, but the sutures rarely, if ever, become parallel and still follow a curved axis. The umbilical area is usually marked by an irregular calcareous boss. The sutures, in general, are elevated, slightly oblique and extend from the keel to the umbonal area. The aperture is radiate on the periphery.

This species differs from *Lenticulina washitensis* (Carsey) in sutural prominence and the tendency to develop a looser coil in maturity. *L. washiten-*

sis is usually smooth-sided, tightly coiled, and when elevated sutures are present they do not extend much more than midway toward the keel from a prominent smooth umbo.

Associated with the more tightly coiled tests of *Astacolus comanchensis* are occasional smaller specimens whose final chambers do not reach back to the umbonal area. These individuals commonly have depressed sutures between these chambers, thus producing an inflated appearance not characteristic of the more involuted chambers. These uncoiled specimens are placed under *Marginulina cyprina* Vieaux (1941, p. 675) although they may be only aberrant forms specifically identical with *Astacolus comanchensis*.

Appearing to be most common in the sandier argillaceous phases of deposition, this species is represented in my collections from the Kiamichi, Denton, Weno, Main Street and Grayson formations.

Greater diameter of holotype 0.9 mm.; lesser diameter 0.65 mm.; thickness through the umbonal area 0.29 mm.

Holotype (Cushman Coll. No. 36363) from brown sandy clay in the upper portion of the Kiamichi formation, station T-85-2.

Genus MARGINULINA d'Orbigny, 1826

MARGINULINA CYPRINA Vieaux

Pl. 2, Fig. 9

Marginula cyprina Vieaux, 1941, Jour. Pal. **15**(6):625, pl. 85, figs. 3a-b. (Denton of north Texas).

This species has the same biostratigraphic distribution as *Astacolus comanchensis*.

Hypotype (Cushman Coll. No. 36364) from brown sandy clay in the upper portion of the Kiamichi formation, station T-85-2.

MARGINULINA TENUISSIMA Reuss

Pl. 4, Fig. 12

Marginulina tenuissima Reuss, 1863, Akad. Wiss. Wien., Sitz. **46**:61, pl. 5, fig. 18; p. 92, pl. 12, fig. 12. (*Minimus*-clay of north Germany).

Marginulina tenuissima Reuss, Chapman, 1894, Roy. Micr. Soc., Jour., no. 3 (5):162, pl. 4, fig. 19. (Gault, zone 11, Folkestone, England).

Marginulina tenuissima Reuss, Egger, 1899, Kön. bayer. Akad. Wiss. München, Abhandl., Cl. 2, **21**:97, pl. 10, fig. 23. (Cretaceous of Bavaria).

Marginulina tenuissima Reuss, Tappan, 1940, Jour. Pal. **14**(2):101, pl. 17, figs. 9-10. (Grayson of north Texas).

This delicate, small, species is distinguished by 12 or more fine longitudinal ribs that are usually twisted slightly about the test. In the deposits studied it is sparsely represented only in the Kiamichi formation. Scattered occurrences,

particularly in clays, within the Washita group of north Texas have been noted.

Hypotype (Cushman Coll. No. 36365) from dark sandy shale in the Kiamichi formation, middle portion, station T-49-10.

Genus LINGULINA d'Orbigny, 1826

LINGULINA FURCILLATA Berthelin

Pl. 4, Fig. 14

Lingulina furcillata Berthelin, 1880. Soc. géol. France, Mém., sér. 3, **1**(5):65, pl. 4 (27), figs. 6a-c. (Albian of France).

Lingulina furcillata Berthelin, Tappan, 1940, Jour. Pal. **14**(2):106, pl. 16, figs. 18a-c. (Grayson of north Texas).

This small species is represented in all Fredericksburg formations though never in abundance. Its rarity may be explained in part by the fact that its size permits it to be overlooked in the finer screenings. Ranging into the Washita, its observed occurrences indicate that the species is more common in dominantly argillaceous dark-colored sediments.

Hypotype (Cushman Coll. No. 36366) from the Goodland formation, station T-85-13, dark marls in the upper portion of the formation.

Genus NODOSARIA Lamarck, 1812

NODOSARIA aff. OBSCURA Reuss

Pl. 4, Fig. 13

Nodosaria obscura Ruess, 1845, Verstein. böhm. Kreide, (1):26, pl. 13, figs. 7-9. (Upper Cretaceous of Germany).

Nodosaria obscura Reuss, Berthelin, 1880, Soc. géol. France, Mém., sér. 3, **1**(5):31, pl. 1, figs. 17a-b. (Albian of France).

Nodosaria obscura Reuss Chapman, 1893, Roy. Micr. Soc., Jour., no. 11, (4):593, pl. 19, fig. 16. (Gault of Folkestone, England).

Nodosaria fragilis Carsey, (not DeFrance), 1926, Univ. Texas Bull. **2612**:35, pl. 4, fig. 1. (Del Rio of central Texas).

Nodosaria obscura Reuss, Plummer, 1931, Univ. Texas Bull. **3101**:156, pl. 11, fig. 3. Del Rio of central Texas).

Nodosaria obscura Reuss, Tappan, 1940, Jour. Pal. **14**(2):104, pl. 16, figs. 7a-8b. (Grayson of north Texas).

A partial synonymy of this long-ranging, widely distributed Cretaceous species is given above.[10] Rare occurrences have been noticed in Goodland and Kiamichi concentrates.

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10 For other references, particularly Upper Cretaceous, see Cushman, 1940, Contr. Cushman Lab. Foram. Res. **16**(4):90, and Ellis and Messina, 1940, Catalogue of Foraminifera, **16**.

Texas Lower Cretaceous specimens assigned in the past to *Nodosaria obscura* Reussa are believed specifically distinct from Reuss' species. Topotypes from the Plänermergel of Luschitz, Bohemia, identified by Reuss himself are in the Cushman Laboratory and have been seen by the writer. These types generally are larger and more pointed on the apertural end than Fredericksburg and Washita specimens. Vieaux described *Nodosaria harrisi* and *N. barkeri* from the Denton of north Texas. These two species are believed to account for most, if not all of the past records of *N. obscura* Reuss in the Texas Lower Cretaceous. Reuss' species is believed by the writer to be confined to the Upper Cretaceous, at least in Texas. For the present the Fredericksburg specimens studied are listed as *Nodosaria* aff. *obscura* Reuss.

Hypotype (Cushman Coll. No. 36367) from blue-gray marls of the Goodland formation, station T-63-5.

Genus PALMULA Lea, 1833

PALMULA LEAI Loeblich and Tappan

Pl. 1, Figs. 6a-b

Palmula leai Loeblich and Tappan, 1941, Bull. Amer. Paleontology **26**(99):336, pl. 47, figs. 1-2. (Duck Creek of north Texas).

Kiamichi specimens from station T-125-1 appear to be referable to this species. Duck Creek specimens obtained from station T-49-16, near the type locality and from the type horizon, are sometimes slightly larger with more chambers but these differences are not believed to warrant specific distinction.

The compressed test is sub-elliptical with a smooth rounded periphery. In the early coiled portion are 4 to 6 lenticuline chambers, visible externally, followed usually by 2 chambers transitional in form preceding the chevron-shaped chambers. The latter chambers number 5 to 9 or more in number, each chamber tapering from the apex posteriorly. The unornamented sutures are distinct and slightly raised, but successively younger sutures decrease in elevation. Inter-sutural areas are unmarked and the radiate aperture is somewhat projecting.

This species is doubtfully present in the Goodland, common in the very marly facies of the Kiamichi, and abundant in the Duck Creek marls near the type locality. The genus *Palmula* as represented in my collection and as reported by Loeblich and Tappan (1941) is almost entirely restricted to marly deposits. Very rare in the marls of the Goodland, it becomes common in the most marly facies of the Kiamichi and then in the Washita is most common in the marls of the Duck Creek, Fort Worth, and Main Street formations although present in the Denton, Pawpaw and Grayson clays.

Hypotype (Cushman Coll. No. 36368) from the Kiamichi formation, station T-85-2, blue-brown clay-marl within the lower middle portion of the formation.

Genus VAGINULINA d'Orbigny, 1826

VAGINULINA INTUMESCENS Reuss

Pl. 4, Fig. 10

Vaginulina intumescens Reuss, 1862 (1863), Sitz. Akad. Wiss. Wien **46**:49, pl. 4, fig. 2. (Gault of north Germany).

Vaginulina intumescens Reuss, Cushman and Alexander, 1930, Contr. Cushman Lab. Foram. Res. **6**(1):5, pl. 2, figs. 1-6. (Goodland of north Texas).

This species is widely distributed but in north Texas is restricted to Fredericksburg deposits. At different levels in the Walnut and Goodland *V. intumescens* Ruess is very abundant.

Vaginulina intumescens differs from *V. complanata* Reuss and its striated variety, with which it is most likely to be confused, in the rounded protuberant outline of the ventral margin. This feature is constant and sufficient for distinction. Striae and costae are generally present on the faces of *V. intumescens* but differ from those on *V. complanata* var. *perstriata* Tappan in being parallel to the dorsal margin whereas those of the latter variety are oblique to the dorsal margin.

Occurring in greatest number in the marls of the Walnut and Goodland, this species is thought to be confined to the Fredericksburg.

Hypotype (Cushman Coll. No. 36369) from the basal foot of Kiamichi dark shale, station T-85-17.

VAGINULINA MARGINULINOIDES Reuss

Pl. 4, Fig. 7

Vaginulina marginulinoides Reuss, 1862 (1863), Sitz. Akad. Wiss. Wien., **46**:44, pl. 3, fig. 2. (Gault of north Germany).

Vaginulina incompta Reuss, l.c.; 45, pl. 3, fig. 5. (Ibid.).

Vaginulina marginulinoides Reuss, Cushman and Alexander, 1930, Contr. Cushman Lab. Foram. Res. **6**(1):5, pl. 1, figs. 23-26. (Goodland of north Texas).

This species has been observed in Goodland concentrates only and those occurrences are confined to the middle and upper portions of the formation. It has not been recorded or observed in any Washita concentrates collected by the writer. *Vaginulina marginulinoides* Reuss is distinguished from *V. recta* Reuss and *V. kochii* Roemer, common in the Washita, in that its sutures are flush or slightly depressed.

Hypotype (Cushman Coll. No. 36370) from blue marl 50 to 55 feet below the top of the Goodland formation, station T-85-8.

Genus BULLOPORA Quenstedt, 1856

Bullopora irregularis sp. nov.

Pl. 1, Fig. 9

Bullopora sp., Tappan, 1940, Jour. Pal., **14**(2):115, pl. 18, fig. 7. (Grayson of north Texas).

Tappan (1940) describes this species as follows:

> Test attached, irregular in shape with numerous tubes arising from the central portion, and occasional chamber has raised central bulbs, similar to *B. laevis* (Sollas) and *B. cervicornis* (Chapman), to one of which it may later be referred.

Specimens differing from *B. laevis* in irregularity and from *B. cervicornis* in greater tube diameter and multifurcate rather than dichotomous branching have been observed in all Fredericksburg formations. This type of bulloporan is present also throughout the Washita group. A check of the organic fragments to which this species and the following, *B. laevis*, are attached reveals that the species are mostly found on pectens and gryphaeas in the upper Washita, oysters and echinoids in the lower Washita, and mainly on echinoids in the Fredericksburg.

Length of central bulb of holotype 0.6 mm.; width of bulb 0.3 mm.; average diameter of tubes 0.1 mm.

Holotype (Cushman Coll. No. 36371) from blue marl near the middle of the Goodland formation, station T-85-14.

BULLOPORA LAEVIS (Sollas)

Pl. 3, Fig. 2

Webbina laevis Sollas, 1877, Geol. Mag., n.s., dec. 2, **4**(3):103, pl. 6, figs. 1-3 (Cambridge greensand of England).

Vitriwebbina laevis (Sollas), Chapman, 1896, Roy Micr. Soc., Jour.: 585, pl. 12, fig. 12. (Gault of Folkestone, England).

Bullopora laevis (Sollas), Tappan, 1940, Jour. Pal. **14**(2):115, pl. 18, fig. 6. (Grayson of north Texas).

Occasional specimens of this linear, oval-chambered species have been observed in Goodland and Walnut concentrates in addition to several Washita occurrences. The species appears to be most common in the Grayson formation.

Hypotype (Cushman Coll. No. 36372) from brownish clays in the upper portion of the Walnut formation, station T-64-5.

Genus VIRGULINA d'Orbigny, 1826

VIRGULINA PRIMITIVA Cushman

Virgulina primitiva Cushman, 1936, Special Publ. **6**, Cushman Lab. Foram. Res.: 46, pl. 7, figs. 1a-c. (Goodland of north Texas).

Virgulina primitiva Cushman, Cushman, 1937, Special Publ. **9**, Cushman Lab. Foram. Res.: 2, pl. 1, figs. 1-3. (Goodland of north Texas).

Cushman has recorded this very small species from the Goodland and Kiamichi formations of north Texas. Specimens from additional Kiamichi

localities (stations T-49-10 and T-49-16) extend the geographical range of this species.[11]

Genus BOLIVINA d'Orbigny, 1839

BOLIVINA cf. TEXTILARIOIDES Reuss

Pl. 4, Figs. 11a-b

Bolivina textilarioides Reuss, 1862 (1863), Sitz. Akad. Wiss. Wien., **46**(1):81, pl. 10, figs. 1a-b. (Lower Cretaceous of north Germany).

Bolivina textilarioides Reuss, Cushman, 1937, Contr. Cushman Lab. Foram. Res. Special Publ. **9**:37-38, pl. 5, fig. 18. (Lower Cretaceous of north Germany).

Specimens from one Walnut concentrate, station T-64-5, agree in all essential details with Reuss' original illustration. The test is elongate, tapered, biserial throughout, slightly compressed; sutures depressed, convex toward the initial end; aperture narrow, elongate, in the medial line. The Walnut specimens differ, however, in that the chambers appear more inflated than those illustrated by Reuss, and the final chamber or pair of chambers are slightly twisted on the long axis.

Length of hypotype 0.68 mm.; greatest width 0.33 mm.; greatest thickness 0.21 mm.

Hypotype (Cushman Coll. No. 36373) from the Walnut formation, station T-64-5, blue shelly marl about 10 feet above the base of the formation.

Genus PATELLINA Williamson, 1858

PATELLINA SUBCRETACEA Cushman and Alexander

Pl. 4, Fig. 8

Patellina subcretacea Cushman and Alexander, 1930, Contr. Cushman Lab. Foram. Res. **6**(1):10, pl. 3, figs. 1a-b. (Goodland fm. of north Texas).

Patellina subcretacea is tiny, low and scale-like with translucent calcareous walls. Common to abundant occurrences in north Texas are diagnostic of the Walnut and Goodland formations. It is found in the marly phase of the Kiamichi and ranges through the marls of the Duck Creek and Fort Worth of the Washita group. I have not observed the species above the Denton nor below the Walnut.[12]

Hypotype (Cushman Coll. No. 36374) from the Walnut formation, station T-64-5, from blue shelly marl 17 feet above the Paluxy sand.

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11 Cushman (1936, p. 46) described another virguline from the north Texas Fredericksburg as *Virgulina subcretacea*. I have not been able to identify this species from material at the type locality (station T-85-14) or from any other locality. It may be that *Virgulina subcretacea* and *Verneuilina schizea* Cushman and Alexander are identical.

12 Vanderpool (Jour. Pal. **7**(4):409, 1933) apparently confused the form described as *Conorbina conica*, sp. nov., with the true *Patellina subcretacea*. I find the former only in material from Vanderpool's southern Oklahoma locality.

Genus CONORBINA Brotzen, 1936

Conorbina conica sp. nov.

Pl. 2, Figs. 6a-c, 7

Test small, an elevated spire with the dorsal side convex and the ventral side slightly concave. The peripheral outline is rounded and usually distinct, gently inflated chambers are narrow and strongly curved. The initial whorl is tightly coiled and composed of 4 or 5 small globular chambers. Depressed, distinct sutures add to the apparent inflation of the chambers. The smooth calcareous wall is usually opaque. The aperture is ventral and consists of a narrow conspicuous slit under the edge of the septal face in the umbilical excavation.

Cushman and Alexander (1930, p. 12) reported that this form was very similar to *Patellina antigua* Chapman. Lacking topotype material from the Cretaceous (Bargate Beds) of Surrey, England, with which to compare the Texas form, the latter is described as new. Comparison with Chapman's figures (1894, figs. 12a-c) brings out several differences. Chambers of the later whorls of *Patellina antigua* are semi-globular and number 12 to 15 to the whorl; those of *Conorbina conica* are narrow, arcuate, and few in number per whorl. The ventral view of Chapman's species does not show the type or location of the aperture, and the spiral test is much more compressed than *Conorbina conica*.

This species has been observed only in Trinity and Fredericksburg sediments. It is abundant to common in the limy portions of the Glen Rose, Walnut, Goodland and Kiamichi formations.

Diameter 0.48 mm.; height 0.30 mm.

Holotype (Cushman Coll. No. 36375) from the upper *Orbitolina* horizon of the Glen Rose, station T-84-1. *Paratype* (Cushman Coll. No. 36376) from blue marls within the upper 20 feet of the Goodland formation, station T-85-13.

Genus GLOBIGERINA d'Orbigny, 1826

GLOBIGERINA PLANISPIRA Tappan

Pl. 3, Fig. 5

Globigerina planispira Tappan, 1940, Jour. Pal. **14**(2):122, pl. 19, figs. 12a-c. (Grayson of north Texas).

Specimens agreeing with Tappan's description and figures are common to abundant in many Kiamichi concentrates, being most plentiful in clays. It is reported to occur throughout the Washita group.

This species is easily distinguished from *Globigerina washitensis* Carsey by its smaller size and smooth finish.

Hypotype (Cushman Coll. No. 36377) from the Kiamichi formation, station T-49-10, hard gray shale 29 feet above the top of the Goodland limestone.

GLOBIGERINA WASHITENSIS Carsey

Pl. 3, Fig. 4

Globigerina sp., Margaret Carpenter, 1925, Univ. Texas Bull. **2544**, pl. 17, fig. 5. (Washita of north Texas).

Globigerina washitensis Carsey, 1926, Univ. Texas Bull. **2612**:44, pl. 7, fig. 10; pl. 8, fig. 2. (Del Rio of central Texas)

Globigerina washitensis Carsey, Plummer, 1931, Univ. Texas Bull. **3101**:193, pl. 13, fig. 12. (Del Rio of central Texas).

Globigerina washitensis Carsey, Tappan, 1940, Jour. Pal. **14**(2):122, pl. 19, figs. 13a-c. (Grayson of north Texas).

This long-ranging Comanchean species is present in Goodland and Kiamichi concentrates but has not been observed in Walnut material from the area studied. The species is common throughout the Washita group and has been reported by Plummer (1930, p. 194) from the Walnut formation of central Texas. Further search will probably reveal its presence in the Walnut formation of this area. *Globigerina washitensis* Carsey is very coarsely reticulate, and since it is a pelagic species, is useful as an index fossil for the middle and upper groups of Comanchean strata in Texas.

Hypotype (Cushman Coll. No. 36378) from the Kiamichi formation, station T-49-10, hard gray shale 26 feet above the top of the Goodland limestone.

Paleoecology

Few, if any, of the species determined in this study are represented in modern seas; it is difficult, therefore, to apply the principles of ecology as has been done so admirably for the Miocene Foraminifera of California by Kleinpell (1938), for some Tertiary Foraminifera of Venezuela by Hedberg (1934), and for Pleistocene Foraminifera from submarine Atlantic cores by Cushman, Henbest and Lohman (1937), by Phleger (1939), and by Cushman (1941).

Most workers have not considered the effects of variable factors on the distribution of the Foraminifera. Among the few papers dealing with these organisms in that manner may be mentioned those of Vaughan (1933, 1940), Norton (1930), Natland (1933), Stubbs (1939), Myers (1935), Cushman (1939), and Schenck (1928, 1940).

Data on the bathymetric, thermal, and geographic distribution of living genera of Foraminifera that lived during Trinity and Fredericksburg times suggest the following generalizations:

1. The genera are most common in shallow waters, though some are represented at depths greater than 3500 fathoms.

2. They are most common in warm waters, though some are represented by species preferring low temperatures.

3. Geographically, most of the genera are more common in tropical and warm temperate environments than in arctic or boreal regions.

Temperature.—Thermal restriction is commonly considered the most important factor limiting the distribution of recent Foraminifera. Near-surface forms with restricted depth range are ideal for the determination of the temperature factor. Thus *Globigerinoides rubra* d'Orbigny and *G. sacculifera* H. B. Brady are considered good indicators of warm water, while *Globigerina pachyderma* Ehrenberg and *Cassidulina subglobosa* H. B. Brady are relatively good indicators of shallow, cool water.

From the implication of warm water suggested by the corals of the Trinity and Fredericksburg groups, it may be tentatively assumed that the temperature range, for at least a portion of the time represented, would fall within the subtropical and tropical zones of Vaughan (1940, p. 144) or between 15°-36° C .The temperature determinations given by Norton (1930, p. 332) for his bathymetric zones A and B range from 18.9°-31.4° C. and are classified by Vaughan (1940, p. 453) as subtropical. Norton's conclusions on the distribution of families that are applicable to the present work indicate that the factors associated with depth (such as photosynthetic action and kind of bottom material) are perhaps more important than temperature alone. For example, the temperature range of Norton's zone A is between 21° and 32° C. and the depth range is from the beach to 5 fathoms. Miliolidae are generally common to abundant in this zone. The next lower zone, B, has practically the same temperature limits, 20° to 31° C. The depth range, however, is from 5 to 60 fathoms. The Miliolidae show a marked decrease in number of species and individuals, while the Lagenidae, Textulariidae and Buliminidae are often common. The great number of miliolid individuals present in Glen Rose and Edwards material thus suggests very shallow warm waters. The almost complete absence of miliolids and the comparative prominence of the Lagenidae, Textulariidae and Bulminidae in the Fredericksburg concentrates suggest deeper, though still relatively shallow, warm water during that epoch.

Depth.—As a limiting factor for the distribution of Foraminifera, depth may be deceptive in its application to fossil assemblages. Pelagic forms, living near the surface, may be found after burial in sediments deposited under almost any depth. Forms assumed to be benthonic are as likely to be controlled by the type of bottom as by the depth of water. Until living specimens are collected from different depths, different types of bottom, and from different associated floras and faunas, the factor of depth is of unknown magnitude in an equation of countless variables. Cushman (1939) has ably indicated the confusion that may arise when ecologic conditions are not fully understood.

Norton's limit of 5 fathoms for the abundant occurrence of recent miliolids in the West Indian region agrees with Scott's conclusion (1940b) as to the depth of Glen Rose seas in north Texas. Scott's limit of 5-7 fathoms was based upon the presence of oyster beds, extensively ripple-marked strata, beds with borings of clams and worms and strata marked by sun-cracks and tracks of land animals. The presence of miliolids, mentioned above, and *Orbitolina* in deposits to be classified as reefs lends support to the conclusion that the Glen Rose seas were very shallow.

The bottom depth of Fredericksburg seas, according to Scott (1940b),

FORAMINIFERA	TRINITY						FREDERICKSBURG																															WASHITA
	GLEN ROSE						WALNUT								GOODLAND															KIAMICHI								
	T-84-1	T-84-2	T-84-3	T-84-4	T-101-3	T-101-5	T-49-7	T-64-5	T-84-5	T-84-6	T-101-1	T-101-2	T-185-1	O-43-1	T-48-7	T-63-1	T-63-5	T-63-6	T-64-2	T-84-7	T-85-7	T-85-8	T-85-13	T-85-14	T-85-15	T-85-16	T-99-3	T-101-6	T-125-2	T-48-2	T-49-10	T-49-16	T-85-2	T-85-15	T-85-17	T-99-3	T-125-1	
AMMOBACULITES GOODLANDENSIS Cushman & Alexander													X			X	X		X		X	X	X	X	X	X			X								X	X
" LAEVIGATA n. sp.								X					X			X			X							X			X		X		X					
" SUBCRETACEUS Cushman & Alexander							X														X								X									X
" SUBGOODLANDENSIS Vanderpool								X					X	X			X							X		X			X									
ASTACOLUS COMANCHENSIS n. sp.																																	X	X				X
BOLIVINA cf TEXTILARIOIDES Reuss								X																														X
BULLOPORA IRREGULARIS n. sp.																					X		X									X			X		X
" LAEVIS (Sollas)									X									X				X						X										X
CONORBINA CONICA n. sp.	X							X	X			X	X	X		X					X	X	X		X		X	X										
COSKINOLINA ADKINSI Barker													X										X		X		X	X	X									
DENTALINA COMMUNIS d'Orbigny																						X	X	X	X				X							X		X
" DEBILIS (Berthelin)																							X		X													X
FLABELLAMMINA ALEXANDERI Cushman								X	X				X		X	X	X	X	X		X	X	X	X	X	X	X	X	X				X		X	X	X	X
FRANKEINA ACUTOCARINATA Alexander & Smith																																					X	X
" GOODLANDENSIS Cushman & Alexander																X	X		X			X	X				X	X							X		X	X
GLOBIGERINA PLANISPIRA Tappan																														X	X	X	X					X
" WASHITENSIS Carsey																							X		X	X			X		X	X						X
HAPLOPHRAGMOIDES GLOBOSA n. sp.																					X	X	X		X													
" TRINITENSIS n. sp.	X		X	X	X	X																																
LINGULINA FURCILLATA Berthelin								X					X								X		X													X		X
LITUOLA CAMERATA n. sp.																	X		X	X	X	X	X	X		X		X	X									
" INFLATA n. sp.	X	X	X	X	X	X		X	X	X	X	X	X			X	X		X	X	X	X	X				X	X									X	
MARGINULINA CYPRINA Vieaux																																	X	X				X
" TENUISSIMA Reuss																															X		X					X
NODOSARIA aff OBSCURA Reuss																	X								X													X
ORBITOLINA CONCAVA TEXANA (Roemer)	X												X																									
PALMULA LEAI Loeblich & Tappan																		X															X				X	X
PATELLINA SUBCRETACEA Cushman & Alexander								X	X		X	X	X		X	X					X	X	X				X		X								X	X
PLACOPSILINA LONGA Tappan																												X	X							X	X	X
SPIROPLECTAMMINA ALEXANDERI Lalicker								X									X			X	X	X	X	X	X	X			X									X
" GOODLANDANA Lalicker																						X																
" SCOTTI Cushman & Alexander																						X				X			X				X					X
" cf WHITNEYI Cushman & Alexander																																	X					
TEXTULARIA RIOENSIS Carsey								X	X				X	X		X	X	X			X	X	X		X	X			X				X			X		X
TROCHAMMINA DEPRESSA n. sp.																														X	X	X	X					
VAGINULINA INTUMESCENS Reuss								X	X				X	X		X	X	X	X		X	X	X	X		X			X					X	X			
" MARGINULINOIDES Reuss																X	X	X				X																
VERNEUILINA SCHIZEA Cushman & Alexander								X	X				X				X		X		X	X	X					X	X									
VIRGULINA PRIMITIVA Cushman																															X	X						

Fig. 21. Occurrence of Trinity and Fredericksburg Foraminifera in north Texas outcrop samples.

was between 5-7 and 20 fathoms. Such shallow neritic bottoms are characterized by "quantities of echinoids and a great variety of large, thick-shelled pelecypods and gastropods. The presence of broad parapipple marks and quantities of *Ostrea* and *Gryphaea* indicate that such bottoms did not exceed a depth of 20 fathoms." It has already been noted that Lagenidae, Textulariidae and Buliminidae are common in the Fredericksburg and in the West Indian region today indicate depths ranging to 60 fathoms. This possible range on the basis of modern Foraminifera is slightly greater than that of Scott based on lithologic and molluscan data.

Salinity.—No genus of Foraminifera represented in the material studied is restricted to brackish or fresh water. Observations of living species by Hedberg (1934) and Schenck (1940) indicate that *Rotalia beccarii* (Linné) and *Quinqueloculina fusca* H. B. Brady prefer water of less than normal sea water salinity as their environment. The presence of those species in any abundance in pre-Recent sediments, then, may be interpreted to indicate brackish-water deposition. Since such a direct method is impossible in determining Comanchean environments, it is necessary to evaluate this factor of salinity on the basis of presence or absence of associated faunal assemblages.

Echinoids, cephalopods and brachiopods are absent from certain Glen Rose strata. These exclusively marine groups are replaced by a fauna composed of ostracodes, bryozoans, pelecypods and gastropods, all of which are represented in fresh or brackish waters as well as marine waters. If the postulate that Glen Rose seas were very shallow is correct, we may assume that their salinity would be affected by torrential rains or by run-off from nearby lands. Miliolids are commonly represented in the possible brackish-water environment. More normal salinity, for example, is indicated by the presence of *Orbitolina* and *Conorbina*. These genera, in the Glen Rose, are always associated with echinoids.

Bottom material.—Since the majority of Foraminiferal genera are benthonic, the type of bottom material probably is more important in their distribution than are most of the other ecologic factors. Concentrations of quartz sand seem to be avoided as habitats; samples of the Paluxy sand are barren of Foraminifera though ostracodes are common. Sandy phases of the Glen Rose and Kiamichi rarely contain Foraminifera but usually yield ostracodes, fish remains, and other organic fragmentals. Even genera with agglutinated tests such as *Textularia*, *Ammobaculites*, *Spiroplectammina* and *Flabellamina* are found most commonly in sediments of which quartz sand is but a minor constituent. Chemical factors, such as the pH value, associated with silica in sea water may be responsible for the apparent dislike of such material as a habitat. The presence of calcareous-shelled ostracodes, usually in an excellent state of preservation, lessens the possibility that originally calcareous tests of Foraminifera were removed through subsequent solution.

Argillaceous and calcareous muds appear to have been most favored by benthonic Foraminifera. The Goodland formation, least siliceous and most calcareous of the formations studied, contains the most varied fauna in number of individuals, species and genera. The Walnut formation has quartz sand

grains throughout but is still calcareous and ranks second to the Goodland in faunal variety. The Kiamichi is typically argillaceous and is rather meager in faunal content.

Stagnation.—The effect of stagnant bottoms rich in hydrogen sulphide upon foraminiferal life is uncertain but apparently hostile, for studies of recent samples from such bottoms never mention foraminiferal tests or living specimens. Since stagnation is believed to have been the principal factor limiting the foraminiferal fauna in the Red River area during Kiamichi time, pertinent observations on modern black-mud deposition are summarized largely on the basis of Strøm's (1939) discussion:

> Salinity is not an important factor in the deposition of black muds. Such muds have been observed in the process of formation in fresh-water lakes (with very great amounts of organic substance deposited), in Norwegian fjords with salt surface waters and little differences of salinity between surface and bottom, and in water bodies of low surface but high bottom salinity such as the Black Sea.
>
> Depth is not of primary importance in the stagnation of waters and the consequent deposition of foul muds. Deep areas such as those in the Black Sea may be contrasted with coastal swamps of Panama and Costa Rica as reported by MacDonald (1920).
>
> Temperature, as an element of climate, is important in stagnation; in tropical regions the process is favored by regularity of climate with small diurnal or yearly variations. Without such variations and the consequent difference in density between surface and bottom waters, the probability of vertical circulation or "turn over" of waters is greatly reduced. Such a condition eventually leads to depletion of oxygen and concentration of dissolved hydrogen sulphide in the deeper portions. This process is well known from colder climates but results there from other sets of conditions. Kuenen (1939) reports deposits rich in hydrogen sulphide and organic remains from Kaoe Bay of Halmahera Island in the Moluccas. Such an occurrence is especially interesting when compared to stagnant Norwegian fjords because it indicates how much more easily tropical waters stagnate than do those in temperate regions.

The above factors and others concerned with the Kiamichi of the Red River area have been presented in some detail by the writer (1943). Observations based on data obtained from the site of Denison Dam (station T-49-10) suggest that the area was one of stagnation and was characterized by lack of circulation and aeration, and by the deposition of foul, sulphurous muds under reducing conditions resulting from bacterial activity.

Biostratigraphic Notes

In noting the observable relationships between Trinity and Fredericksburg foraminiferal faunas and their containing sediments, a recapitulation of the different bottom types of that time in north Texas will indicate the apparent relative abundance of the benthonic Foraminifera. Limy mud bottoms, represented in outcrops as marls and limestones, exhibited the greatest and most varied population. Argillaceous muds, now clays, clay-marls and shales were the next most populous bottom-living communities. Quartzose sands, now sands or sandstones, were least favorable as a habitat for most species and now yield the poorest fauna in concentrates.

For the presentation of the relationship between fauna and containing sediment, the Duck Creek formation and its fauna may be taken as the stand-

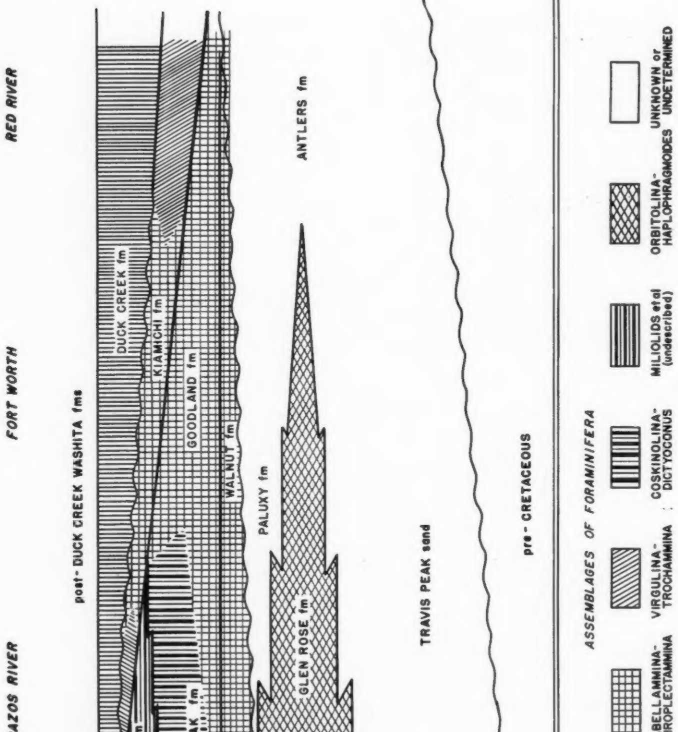


Fig. 22. Outcrop distribution of assemblages of Foraminifera in north Texas.

ard for comparison with observed Fredericksburg and Trinity facies. Figure 22 illustrates the outcrop distribution of assemblages of Foraminifera recognized and discussed below.

The Duck Creek formation throughout its outcrop in north Texas is rather uniform in facies. The upper portion consists of dark brown or gray marls; the lower is more limy in content and consists largely of alternating limestones and marls. Between the Brazos and Red rivers, the faunal change of both large and small fossils is very slight. Some of the described Foraminifera restricted to the Duck Creek or common only in the Washita are *Gaudryinella delrioensis* Plummer, *Textularia washitensis* Carsey, *Spiroplectammina longa* Lalicker, *Vagulina kochii* Roemer, *Flabellammina longiuscula* Alexander and Smith, *Bigenerina wintoni* Cushman and Alexander, *Gaudryina alexanderi* Cushman, *Palmula leai* Loeblich and Tappan and *Tritaxia plummerae* Cushman. This foraminiferal fauna, which may be called the *Palmula-Tritaxia* assemblage, would never be confused with any pre-Duck Creek fauna in the north Texas area, occurs commonly throughout the length of the outcrop and may be taken as a starting point for comparison with older faunas.

The Kiamichi formation exhibits three different assemblages, all fairly well restricted to different types of lithology. The outcrop in Cooke and Grayson counties of the Red River area, is largely composed of dark, pyritiferous, finely laminated shale. Species most common are *Globigerina planispira* Tappan, *G. washitensis* Carsey, *Trochammina depressa* n. sp., and *Virgulina primitiva* Cushman, *Spiroplectammina scotti* Cushman and Alexander, *Trochammina* blage. Farther south, in the Fort Worth area, the lithology is brown to gray shale with several marly levels. Dominant species of this association, the *Flabellammina-Spiroplectammina* assemblage, are *Flabellammina alexanderi* Cushman, *Spiroplectammina scotti* Cushman and Alexander, *Trochammina depressa* sp. nov., and *Astacolus comanchensis* sp. nov. In the Bosque County area, yellow marls and white limestones become the lithologic facies and the fauna has a definite Washita aspect. Species present in considerable number are *Palmula leai* Loeblich and Tappan, *Frankeina acutocarinata* Alexander and Smith and *Placopsilina longa* Tappan in addition to the long-ranging *Lituola inflata* sp. nov., *Flabellammina alexanderi* Cushman, *Conorbina conica* sp. nov, and *Patellina subcretacea* Cushman and Alexander. This association of species is called the *Lituola-Palmula* assemblage.

The Goodland formation is similar to the Duck Creek in consisting largely of one facies along the outcrop. Lithologically, it is composed of gray to blue marls and white limestones. Its association of species, the *Flabellammina-Spiroplectammina* assemblage, does not vary greatly along the outcrop. Species common from the Red River area to Johnson County and southward are *Flabellammina alexanderi, Lituola camerata* sp. nov., *Spiroplectammina alexanderi* Lalicker, *Ammobaculites goodlandensis* Cushman and Alexander, *Lituola inflata, Frankeina goodlandensis* Cushman and Alexander, *Patellina subcretacea, Conorbina conica* and *Vaginulina intumescens* Reuss. South of Johnson County, with the appearance of the Edwards reef facies and an

abundance of miliolids, the foraminiferal aspect of the Comanche Peak is altered from that of the Goodland through the addition of new forms such as *Coskinolina adkinsi* Barker and *Dictyoconus walnutensis* (Carsey).

The marly portions of the north Texas Walnut shell beds contain a foraminiferal fauna similar to the *Flabellammina-Spiroplectammina* assemblage of the Goodland but not as rich in variety. In central Texas, as at the Mount Barker locality, the shell beds constitute but a minor proportion of the total thickness of the formation. There, the clay-marls contain an association of undescribed new species, elements of the *Coskinolina-Dictyoconus* assemblage of the Comanche Peak and traces of the Glen Rose *Orbitolina-Haplophragmoides* assemblage.

The sands of the Paluxy, Antlers and Travis Peak formations are, with but very few exceptions, barren of Foraminifera. One exception encountered is the assemblage of Fredericksburg aspect found by Vanderpool in Paluxy (=Antlers) sandy clays near Marietta, Oklahoma. This occurrence has been discussed in the stratigraphic résumé of the present paper.

The Glen Rose formation is very limy throughout the outcrop length but has occasional sandy clay and marl members. The sandy strata usually yield little variety, miliolids being the predominant forms. The more limy marls and soft limestones often carry *Orbitolina concava texana* (Roemer), *Haplophragmoides trinitensis* sp. nov., *Lituola inflata, Conorbina conica* and *Cuneolina* (?) sp. This association is called the *Orbitolina-Haplophragmoides* assemblage. In Travis County, central Texas, there are additional species, such as *Ammobaculites laevigata* sp. nov., and several undescribed new species that change the faunal aspect slightly.

The Travis Peak formation, in north Texas, has not been thoroughly studied and no foraminiferal fauna is known. In central Texas "*Orbitolina texana*" has been reported from an upper member of the formation. It is probable that detailed collecting of the marls, clays and limestones of the central Texas Travis Peak will reveal a foraminiferal assemblage similar in many respects to that of the north Texas Glen Rose, but sufficiently distinct for differentiation.

Conclusions

The biostratigraphic data presented consist primarily of observations on the occurrence of each species with respect to the lithologic type of containing strata, the vertical and geographic distribution of each species and the relationship between the Foraminifera and associated larger fossils. The general conclusion to be drawn from this data is that full recognition of factors resulting in different facies must be made before these Foraminifera can be used for the differentiation of formations. The recognition of zones and horizons useful to students of subsurface Lower Cretaceous strata must likewise be based upon the precept that Foraminifera, as living animals, were controlled by many variable ecologic factors as well as by the factor of time. Closer cooperation among biologists and paleontologists will result in a more complete understanding of the geologic history of strata in which Foraminifera are present.

Addenda

After the submittal of this manuscript, and in the interim since most of this study was completed, three papers on Comanchean microfossils have been published and other information bearing on the occurrence of several species has been obtained.

Globulina exserta (Berthelin), not discussed in the present paper, has been recorded by Cushman and Ozawa (Proc. U. S. Nat. Museum 77(6):80, 1930) from the "Goodland formation near Fort Worth, Texas."

Raymond E. Peck's valuable contribution, "Lower Cretaceous Crinoids from Texas" (Jour. Paleontology 17(5):451-475, pls. 71-76, September, 1943), indicated the stratigraphic distribution of these common Fredericksburg and Washita microfossils.

The following species known also from Fredericksburg strata are noted and figured in Helen Tappan's comprehensive paper, "Foraminifera from the Duck Creek Formation of Oklahoma and Texas" (Jour. Paleontology 17(5):476-517, pls. 77-83, September, 1943).

Ammobaculites goodlandensis Cushman and Alexander
Frankeina acutocarinata Alexander and Smith
Textularia rioensis Carsey
Placopsilina longa Tappan
Dentalina communis d'Orbigny
Dentalina debilis (Berthelin)
Marginulina tenuissima Reuss
Lingulina furcillata Berthelin
Nodosaria obscura Reuss
Palmula leai Loeblich and Tappan
Bullopora laevis (Sollas)
Bolivina cf. *textilarioides* Reuss
Patellina subcretacea Cushman and Alexander
Globigerina planispira Tappan
Globigerina washitensis Carsey

R. Wright Barker's detailed study of "Some Larger Foraminifera from the Lower Cretaceous of Texas" (Jour. Paleontology 18(2):204-209, pl. 35, March, 1944) contains discussions and figures of the following species referred to in the present text:

Dictyoconus walnutensis (Carsey)
Coskinolina adkinsi Barker
Orbitolina concava texana (Roemer)

In connection with the above paper, it may be mentioned that *Dictyoconus walnutensis* has since been observed by the writer and identified by Barker in an outcrop sample from the Edwards formation. The sample was collected by W. S. Adkins from the Edwards reef limestone in the city of Belton, Bell County, central Texas. The species is associated with a reef biota of several unstudied, apparently undescribed, species.

EXPLANATION OF PLATES

PLATE 1

(Numbers in parentheses are accession numbers of the Cushman Laboratory for Foraminiferal Research. All magnifications are approximate.)

Figs. 1A-B. *Lituola inflata* sp. nov. Side and apertural views of holotype (36339), Kiamichi formation, sta. T-125-1. ×11, p. 547.

Figs. 2-3. *Ammobaculites subgoodlandensis* Vanderpool. 2, side view of hypotype (36313) from the Walnut formation, sta. T-64-5. 3, apertural view of a distorted specimen (36314) from the same locality. ×22, p. 540.

Figs. 4-5. *Lituola camerata* sp. nov. 4, apertural view of paratype (36332), Goodland formation, sta. T-85-15. 5, side view of holotype (36331), Goodland formation, sta. T-85-8. ×22, p. 544.

Figs. 6A-B. *Palmula leai* Loeblich and Tappan. Side and peripheral views of hypotype (36368) from the Kiamichi formation, sta. T-85-2. ×22, p. 558.

Fig. 7. *Frankeina acutocarinata* Alexander and Smith. Hypotype (36325) from the Kiamichi formation, sta. T-125-1. ×22, p. 542.

Figs. 8A-B. *Haplophragmoides trinitensis* sp. nov. Apertural and side views of holotype (36330), Glen Rose formation, sta. T-84-1. ×36, p. 544.

Fig. 9. *Bullopora irregularis* sp. nov. Holotype (36371), Goodland formation, sta. T-85-14, partially obscured by a cemented polymorphinid on the central bulb. ×22, p. 559. (Drawn by Ann Shepard Green)

PLATE 2

Figs. 1A-B. *Astacolus comanchensis* sp. nov. Peripheral and side views of holotype (36363), Kiamichi formation, sta. T-85-2. ×40, p. 555.

Figs. 2-3. *Ammobaculites laevigata* sp. nov. 2, side view of paratype (36302); 3, peripheral view of holotype (36301), both specimens from the Goodland formation, sta. T-63-1. ×45, p. 538.

Figs. 4A-B, 5. *Trochammina depressa* sp. nov. 4A-B, dorsal and ventral views of holotype (36353), Kiamichi formation, sta. T-48-2. 5, ventral view of paratype (36354), Kiamichi formation, sta. T-85-2. ×93, p. 552.

Figs. 6A-C, 7. *Conorbina conica* sp. nov. 6A-C, dorsal, side, and ventral views of holotype (36375), Glen Rose formation, sta. T-84-1. 7, dorsal view of paratype (36376), Goodland formation, sta. T-85-13. ×52, p. 562.

Figs. 8A-C. *Haplophragmoides globosa* sp. nov. Side and peripheral views of holotype (36327), Goodland formation, sta. T-85-8. ×93, p. 543.

Fig. 9. *Marginulina cyprina* Vieaux. Side view of hypotype (36364) from the Kiamichi formation, sta. T-85-2. ×40, p. 556. (Drawings by Ann Shepard Green)

PLATE 3

Fig. 1. *Spiroplectammina scotti* Cushman and Alexander. Hypotype (36349) from the Kiamichi formation, sta. T-85-2. ×50, p. 549.

Fig. 2. *Bullopora laevis* (Sollas), Hypotype (36372) from the Walnut formation, sta. T-64-5. ×10, p. 560.

Fig. 3. *Placopsilina longa* Tappan. Hypotype (36355) from the Kiamichi formation, T-125-1. ×15, p. 552.

Fig. 4. *Globigerina washitensis* Carsey. Hypotype (36378) from the Kiamichi formation, sta. T-49-10. ×75, p. 563.

Fig. 5. *Globigerina planispira* Tappan. Hypotype (36377) from the Kiamichi formation, sta. T-49-10. ×75, p. 562.

Fig. 6. *Verneuilina schizea* Cushman and Alexander. Hypotype (36352) from the Walnut formation, sta. T-64-5. ×75, p. 550.

Fig. 7. *Textularia rioensis* Carsey. Hypotype (36350), elongate form, from the Goodland formation, sta. T-85-8. ×75, p. 551.

Fig. 8. *Frankeina goodlandensis* Cushman and Alexander. Hypotype (36326) from the Goodland formation, sta. T-85-13. ×50, p. 542.

Figs. 9A-B. *Textularia rioensis* Carsey. Hypotype (36351), compressed form, from the Walnut formation, sta. T-64-5. ×75, p. 551. (Drawn by the author)

PLATE 4

Fig. 1. *Ammobaculites subgoodlandensis* Vanderpool. Hypotype (36315) from the Goodland formation, sta. T-85-16. ×15, p. 540.

Figs. 2-3. *Ammobaculites subcretaceus* Cushman and Alexander. 2, hypotype (36311) from the Goodland formation, sta. T-85-8. 3, hypotype (36312), distorted specimen, from the same locality. ×50, p. 538.

Fig. 4. *Ammobaculites goodlandensis* Cushman and Alexander. Hypotype (36300) from the Goodland formation, sta. T-63-1. ×20, p. 537.

Fig. 5. *Spiroplectammina goodlandana* Lalicker. Hypotype (36348) from the Goodland formation, sta. T-85-8. ×100, p. 549.

Fig. 6. *Spiroplectammina alexanderi* Lalicker. Hypotype (36347), Goodland formation, sta. T-85-7. ×100, p. 548.

Fig. 7. *Vaginulina marginulinoides* Reuss. Hypotype (36370) from the Goodland formation, sta. T-85-8. ×33, p. 559.

Fig. 8. *Patellina subcretacea* Cushman and Alexander. Hypotype (36374), Walnut formation, sta. T-64-5. ×100, p. 561.

Fig. 9. *Dentalina communis* d'Orbigny. Hypotype (36361) from the Goodland formation, sta. T-85-8. ×50, p. 554.

Fig. 10. *Vaginulina intumescens* Reuss. Hypotype (36369) from the Kiamichi formation, sta. T-85-17. ×20, p. 559.

Figs. 11A-B. *Bolivina* cf. *textilarioides* Reuss. Hypotype (36373) from the Walnut formation, sta. T-64-5. ×50, p. 561.

Fig. 12. *Marginulina tenuissima* Reuss. Hypotype (36365) from the Kiamichi formation, sta. T-49-10. ×75, p. 556.

Fig. 13. *Nodosaria* aff. *obscura* Reuss. Hypotype (36367) from the Goodland formation, sta. T-63-5. ×50, p. 557.

Fig. 14. *Lingulina furcillata* Berthelin. Hypotype (36366), Goodland formation, sta. T-85-13. ×100, p. 557.

Figs. 15-16. *Flabellammina alexanderi* Cushman. 15, microspheric hypotype (36323) from the Kiamichi formation, sta. T-85-2. ×15. 16, megalospheric hypotype (36324) from the same locality. ×33, p. 541.

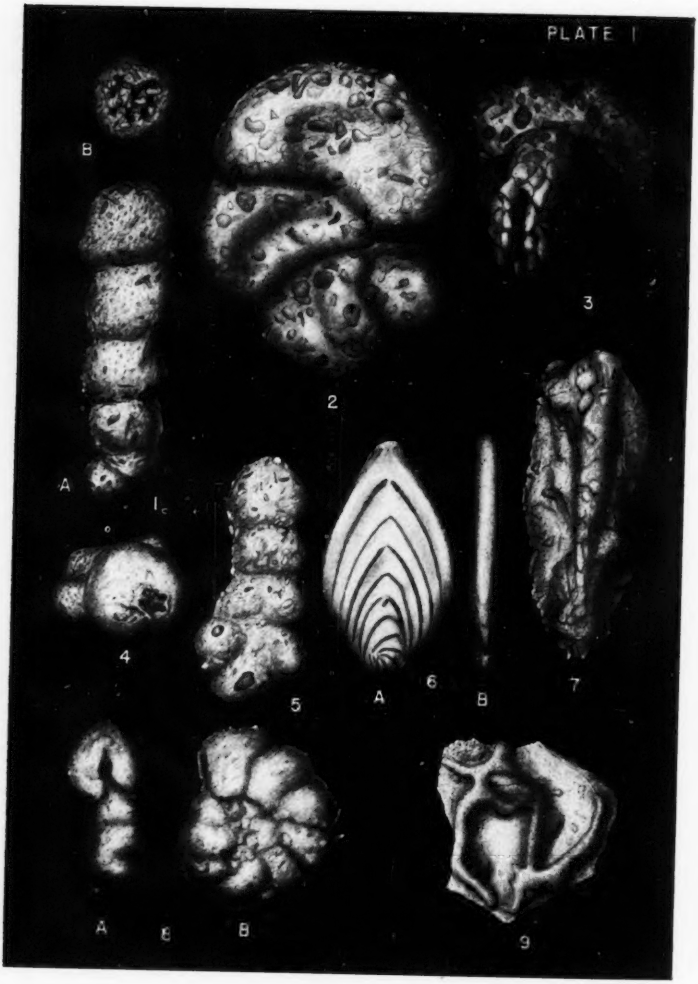
Fig. 17. *Dentalina debilis* (Berthelin). Hypotype (36362) from the Goodland formation, sta. T-85-13. ×50, p. 555. (Drawn by the author)

PLATE 5

Figs. 1-2. *Orbitolina concava texana* (Roemer). Hypotypes from the Glen Rose formation, three miles east of Fischer's Store, Hays County, Texas. ×11, p. 553.

Figs. 3-6. *Coskinolina adkinsi* Barker. Topotypes from the Walnut formation, sta. T-185-1. ×61, p. 550.

Figs. 7-11. *Dictyoconus walnutensis* (Carsey). (Referred to in the text of *Coskinolina adkinsi*.) Topotypes from the Comanche Peak formation, sta. T-185-1. 7-9, ×22.5; 10, ×11; 11 (same specimen as figure 10), ×16.5. (Thin sections and illustrations prepared by R. Wright Barker)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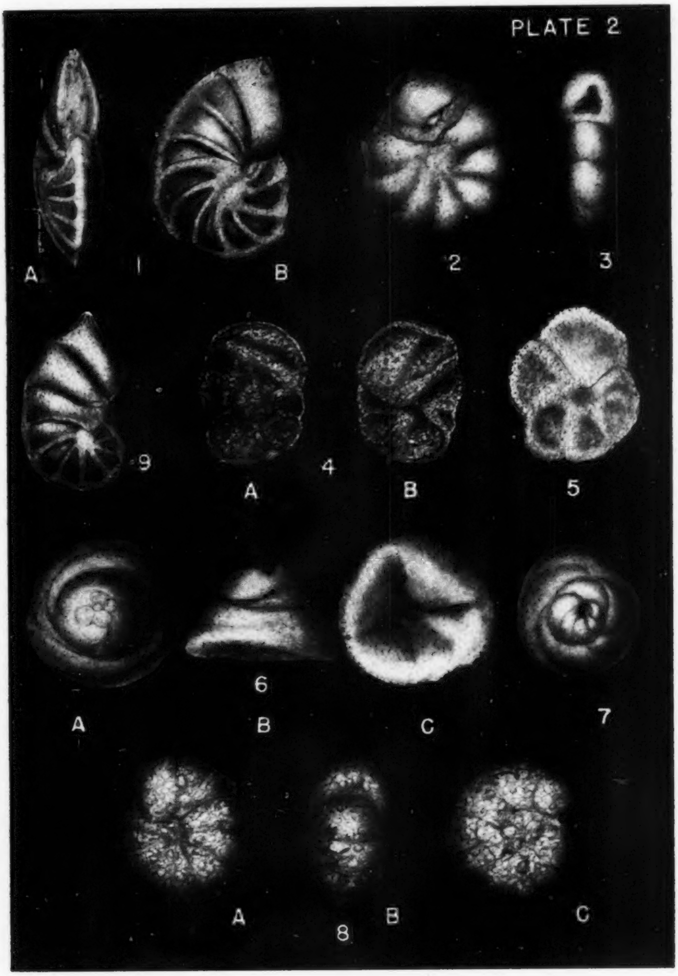
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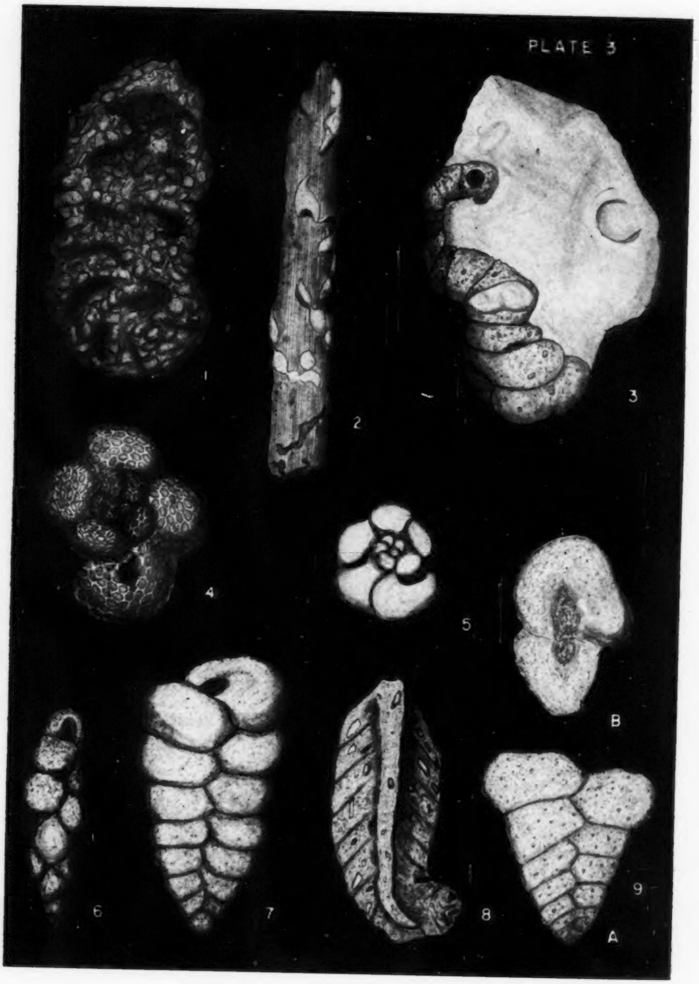
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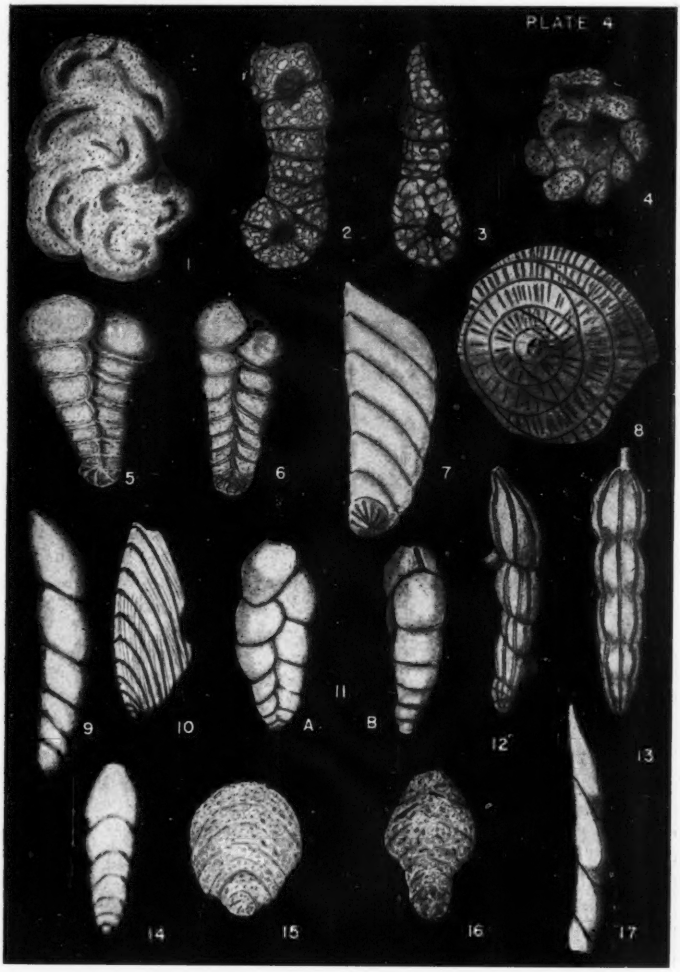
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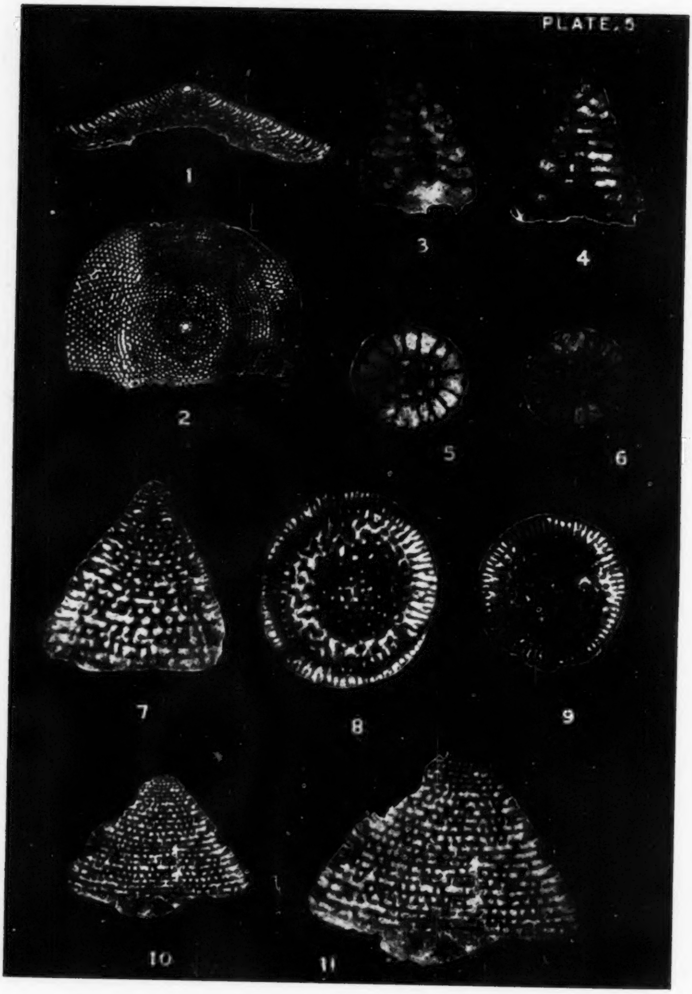
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Aspideretes annae n. sp., a New Species of Soft Shell Turtle from the Bridger Eocene of Wyoming*

Rainer Zangerl

Hay (1908) described among the soft shell turtles of the genus *Aspideretes* from the Bridger Eocene a form, *A. grangeri* Hay, the carapace of which exhibits an unusually shaped first and second pair of costal plates. The first pair is proximally wide, distally narrow, the second pair shows opposite proportions. Hay (*loc. cit.*) describes this feature, pays little attention to it, however, assuming that it is a mere variation.

In 1940 the writer collected an almost complete shell, carapace and plastron, of a form which resembles *A. grangeri* Hay in the similarity of proportions of the first two pairs of costal plates. The differences between the two shells are, however, numerous and the proposal of a new species seems well justified. The species is dedicated to my wife, Ann, who discovered the fossil.

The specimen was embedded in a gray clay, dorsal side up. The shell was disarticulated to some extent and strewn over an area of about two square yards. Some limb bones and fragments of vertebrae were associated with the shell plates, but there was no indication of the presence of the skull. Some of the plates lay piled up on one another, others were found some distance away from the main mass of bones.

The state of preservation of the fossil in the formation recalls similar deposition of skeletons in the marine Triassic (Scisti bituminosi) of Mt. San Giorgio, Tessin, Switzerland, where entire skeletons often are totally disarticulated; Peyer 1935 (*Paraplacodus broilii* Peyer; type and specimen "B"); 1936: *Hescheleria rübeli* Peyer, type. There can be no doubt that the general conditions of burial—in the case of the marine Triassic fossils on one hand and the present turtle from the Bridger Eocene of Wyoming on the other—were very different. A comparison of the similarities and dissimilarities of preservation and deposition in the two cases, however, may aid in the reconstruction of the probable burial circumstances of the present fossil.

In both cases the skeletons are completely disarticulated, yet the bones are not irregularly mixed together, but retain in general their original position in regard to the regions of the skeletons to which they belong. Furthermore the dislocation of bones took place in one direction only, in *Hescheleria rübeli* Peyer from side to side, in *A. annae* parallel to the longitudinal axis of the body.

The fact that almost entire skeletons, totally disarticulated, remained preserved in a restricted area, strongly suggests that they were partially or completely embedded in mud before the final decomposition of the ligaments took place. In the case of the Triassic skeletons from Mt. San Giorgio it is frequently observed that the side of the skeleton which faces down in the formation (and which was facing the sediment at the time of burial) is better

* Contribution from the Department of Biology, University of Notre Dame, Notre Dame, Ind.

preserved than the side which faced the water surface (Peyer, 1936a, p. 58). In *A. annae* both sides are equally well preserved. This phenomenon might indicate a difference in the nature of the burial ground. The bottom of the Triassic sea in that region was probably covered by a relatively firm sediment which did not engulf the carcasses but supported them for some time on its surface. The present turtle probably sank into a deep, soft swamp mud and decomposed in a relatively uniform medium.

It appears more difficult to explain the apparently regular dispersal of the bones on or in the burial ground. Peyer (1935, 1936b) suggests slight water movements, perhaps slow currents in a large body of water over a deep, possibly abiotic, basin.

In the neighborhood of the burial ground of the fossil under consideration there were several fair sized channel fills. One is tempted to think of repeated changes of the water level in the channels accompanied by pressure changes against the surrounding marsh deposits as the cause of slow back and forth movements of large masses of swamp mud which in turn might be responsible for the directed dispersal of a fully decomposed skeleton.

Aspideretes annae n. sp.

Type: Nearly complete carapace and plastron, isolated extremity bones. U.N.D. No. 663.

Locality: Small Bridger exposure immediately north of highway U.S. 30 about 3 miles east of Little America, Sweetwater Co., Wyoming.

Carapace (Fig. 1)

The carapace is oval in shape, but the individual had apparently not reached its full degree of ossification; the ribs protrude on either side from 40 to 50 mm. beyond the pitted shield.[1] A specimen of this species, as maturely ossified as the type specimen of *A. grangeri* Hay, would probably have an almost circular shell, since the carapace of trionychid turtles, once the full set of plates is formed, seems to grow wide without increasing its length proportionately.

A good indication of the relatively immature state of epithecal ossification (Zangerl 1939) is the limited extent of the pitted area on the nuchal plate. The carapace was probably well arched as is indicated by the clefts between the distal ends of some of the costal bones.

The nuchal plate is wide transversally, about half the length of the carapace and it is anteriorly and posteriorly concave. In the middle of the anterior concavity there is a small protuberance. On the ventral aspect the nuchal shows considerable relief. Posteriorly, to either side of the median sagittal plane there are shallow, smooth depressions, presumably for the accommodation of the hook-shaped postzygapophyses of the last cervical vertebra. In front of these depressions there is an equally smooth transverse ridge which

1 Some of these distal rib portions are preserved, but good fracture contacts could not be found except in the case of the one belonging to the second costal of the right side of the shell. The estimate of the original length of these rib ends is therefore conservative.

fans out towards the sides. The lateral ends of the bone are characteristically drawn out into pointed processes with parallel, longitudinal ridges.

The preneural plate is wider than long. In front it reaches the posterior, wide, V-shaped concavity of the nuchal. The remaining part of the outline of the preneural approximates a parabolic curve.

There are six neural plates. The first exhibits a somewhat unusual shape. It is wider in front than in the back. Its anterior end is concave, the sides are but slightly concave. The posterior end is similar in its outline to that of the following neurals. The second neural is missing. Judging from the vacant space left by the adjoining plates, it probably resembled the third neural in every way but in size. It probably was slightly larger. The 3rd, 4th and 5th neural plates exhibit the typical hexagonal shape commonly seen in representatives of the genus. The sixth neural is small; it does not separate completely the corresponding pairs of costals. It is a trifle shorter than the proximal ends of its costal plates are wide.

Of the 8 pairs of costals the last 2 meet in the sagittal plane. The sixth pair is partially separated by the small neural. All the costal plates, with the exception of the first and the seventh are considerably wider laterally than

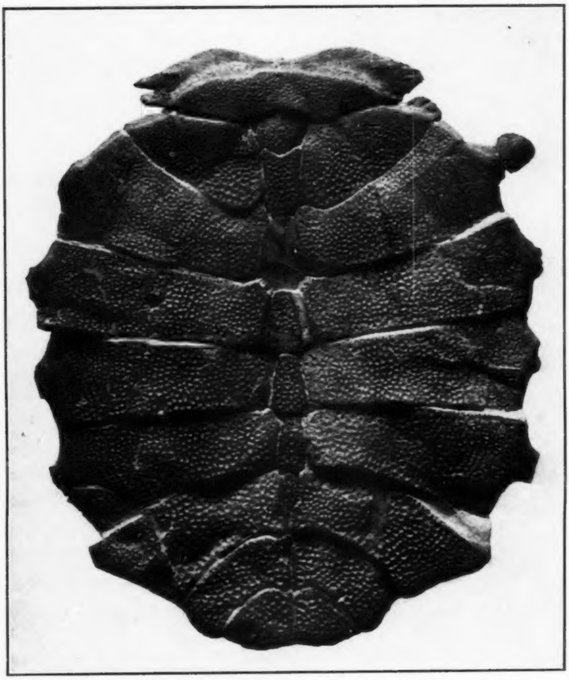

Fig. 1. Carapace of *Aspideretes annae*, type U. N. D. No. 61

medially. This is particularly noticeable in the second pair of costal plates. The first pair on the other hand shows opposite proportions. The anterior and posterior margins of this plate converge laterad at such an angle that it appears possible, that a specimen of this kind with ultimately ossified epithecal shell might show a lateral contact between the nuchal bone and the second pair of costals.

The present form has the first 2 costal plates, in general proportions, like those of *A. grangeri* Hay; but both bones are noticeably wider distally in the latter species. This appears to be due to differences in the values of the angles formed by the ribs and the main longitudinal axis of the shell. In both shells the angle between the rib of the first costal and the longitudinal axis of the body is about the same, approximately 60° to 63°. The corresponding angle of the second pair of costals amounts to about 80° in *A. grangeri* Hay, but only to 67° in the newly proposed species (see further discussion below, p. 590).

While it is generally known to students of chelonian osteology that the particular shapes of shell plates are subject to wide individual variation, especially in the case of the epithecal trionychid armour, the angular values between the ribs and the longitudinal axis of the shell seem to be fairly constant even in specimens of the same species, which may exhibit striking differences in shape and proportion of their carapace elements. This observation was made on a very limited number of shells of *Amyda ferox* from the St.

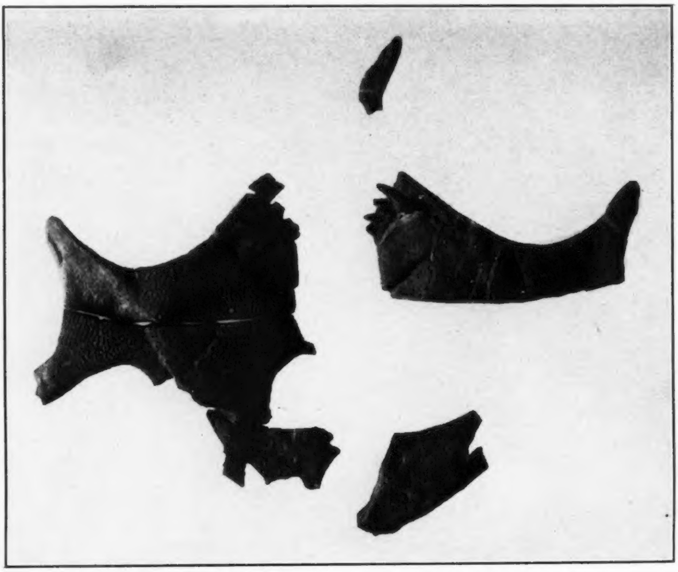

Fig. 2. Plastron of *Aspideretes annae*, type U. N. D. No. 61.

Johns River, Fla., and needs to be confirmed by further study of larger series. Sufficiently large numbers of specimens of several species of recent Emyidae have been thus examined and the results are encouraging.

PLASTRON (Figs. 2 and 3)

The plastron is not completely preserved. The missing elements are: the right epiplastron, the endoplastron and the left hypoplastron. Parts of both xiphiplastra are missing, but fortunately in such a manner that the preserved portions of both elements complement each other, so that the reconstruction (Fig. 3) of the original shape offers little difficulty.

The epiplastron is a relatively small bone considering the size of the specimen. Its anterior, "free" end forms an angle of about 140° to 150° against its posterior process (partially broken off) which accompanied the right posterolateral process of the entoplastron. Immediately posterior to the angulation point and on the dorsal surface of the bone there is a smooth, longitudinal depression for the reception of the entoplastron. Along the lateral edge the epiplastron is relatively thick, while its medial margin is drawn out to the shape of a thin blade.

The epiplastra are rarely preserved in fossil forms. *A. singularis* Hay is the only fossil species of the genus in which the epiplastra are known. Compared with *A. singularis* Hay the anterior process of the element in the present species is relatively longer and instead of being bluntly rounded, it is quite sharply pointed anteriorly.

The hypoplastra are very similar to those of *A. singularis* Hay. They are not quite as deeply concave anteriorly, and their antero-lateral processes point

Fig. 3. Reconstruction of the plastron of *Aspideretes annae*. The dotted areas indicate the approximate extent of the pitted epithecal ossification.

forward and slightly inward, instead of forward and outward as in the compared species. The hypoplastron, too, does not differ significantly from that of *A. singularis*. A slight difference lies in the size of the postero-medial processes which are relatively smaller in the present form.

The xiphiplastra on the other hand can hardly be mistaken for those of *A. singularis*. They are much narrower in antero-posterior direction near their medial margins. The fontanelle, enclosed by the inner borders of the xiphiplastra, is sub-circular in outline rather than oval as in *A. singularis*. Instead of one antero-medial process as in *A. singularis* there are two blunt projections in the present species.

The surface sculpture of the carapace is somewhat irregular. The smaller pits are found in the front part of the shell and along its edges. On some of the plates the marginal pits are arranged in lines, parallel to the edge of the shell, on other plates (e.g., on the costal no. 4, of the left side) the coarser, more medial pits exhibit such arrangement.

TABLE 1.—Measurements of the shell of *Aspideretes annae*.

Carapace:			
Total length of carapace			416 mm
Greatest width of carapace			354 mm
Width of carapace including estimated rib projections			454 mm
Width of nuchal plate (transversally)			208 mm
Length of nuchal plate (sagittally)			38 mm
Length of preneural plate	31 mm	width of same	42 mm
Length of 1st neural plate	40 mm	width of same (posteriorly)	26.5 mm
Length of 2nd neural plate		width of same (posteriorly)	
Length of 3rd neural plate	45 mm	width of same (posteriorly)	27 mm
Length of 4th neural plate	43 mm	width of same (posteriorly)	26 mm
Length of 5th neural plate	38.5mm	width of same (posteriorly)	19 mm
Length of 6th neural plate	24 mm	width of same (posteriorly)	18.5 mm
Width of 1st costal plate, medially	60 mm	laterally	28 mm
Width of 2nd costal plate, medially	54 mm	laterally	84 mm
Width of 3rd costal plate, medially	46 mm	laterally	60.5 mm
Width of 4th costal plate, medially	46 mm	laterally	68.5 mm
Width of 5th costal plate, medially	44 mm	laterally	74 mm
Width of 6th costal plate, medially	44 mm	laterally	71 mm
Width of 7th costal plate, medially	40 mm	laterally	31 mm
Width of 8th costal plate, medially	39 mm	sagittal plane to most distal point	50 mm
Plastron:			
Length of epiplastron, anterior to angulation point			45 mm
Width of hyoplastron, along hypoplastral suture			165 mm
Narrowest part of hyoplastron			40 mm
Narrowest part of hypoplastron			28 mm
Length of xiphiplastra, near medial margin			78 mm
Width of xiphiplastra, between tips of postero-medial and antero-lateral processes			130 mm

Comparison of relative sizes of *A. ellipticus*, *A. grangeri*, *A. annae*

A	90.0	92.3	103.1
B	40.1	51.3	50.0
C	8.1	10.3	9.1
D	30.4	12.5	20.2
E	82.3	110.0	73.8
F	53.6	42.3	51.7
G	85.7	65.4	46.6
H	75.0	52.8	90.0
I	160.0	189.5	155.5

A: total width (including rib ends) .100/ total length of shell;
B: with of nuchal (transversally) .100/ length of shell;
C: length of nuchal (sagittally) .100/ length of shell;
D: width of preneural .100/ width of nuchal;
E: length of preneural .100/ width of preneural;
F: length of preneural .100/ medial width of 1st costal plate;
G: lateral width of 1st costal .100/ medial width of 1st costal;
H: medial width of 2nd costal .100/ medial width of 1st costal;
I: lateral width of 2nd costal .100/ medial width of 2nd costal.

Some Remarks Concerning the Rib Angulation in Trionychid Turtles and the Validity of the Soft Shell Turtle Species

It was suggested above that the angulation of the ribs against the central longitudinal axis of the shell might be less variable than most other characters of the armour, particularly the shape of its constituents. One can easily observe that the costal plates do not always symmetrically overlie their corresponding ribs, e.g., in the case of the 6th costal of *A. annae* the rib is not curved caudad as much as the plate, so that it underlies the antero-lateral corner of the plate. In a specimen of *Amyda ferox* from Florida the 8th pair of ribs underlie the posterior margin of the 7th pair of costal plates. This phenomenon is easily explained by the ontogenesis of the epithecal armour. The epithecal ossifications develop relatively late, at a time when the vertebrae and ribs (and the thecal part of the nuchal plate!, Zangerl 1939), are already well ossified. The epithecal ossifications appear first on the spinal processes of the vertebrae and on the dorsal surfaces of the proximal ends of the ribs. These centers of ossification grow in all directions but evidently not at the same rate of speed, so that the sutures between the future plates lie wherever two areas of ossification happen to meet. This can be observed readily in any age series of shells of a recent species. The particular shapes of the epithecal plates of trionychid turtles are therefore hardly typical for any given species.

The angles formed by the longitudinal axes of the ribs and the main antero-posterior axis of the shell, apparently not influenced by the growth of the armour, seem to be more constant.

These angles were measured (from figures in the literature) for the first 6 ribs in various species of *Aspideretes*.[2] The results are compiled in Table 2.

It is interesting to note that one can divide the species of *Aspideretes* into 4 groups on the basis of these angles.

1. The fifth rib stands at approximately a right angle (88° to 92°) to the vertebral column. The first 4 ribs are bent forward, the 6th faces backward.

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2 All illustrations view the shells from the dorsal side; in some cases the distal ends of the ribs are broken off or overgrown by the epithecal armour. In spite of these difficulties it is possible to measure the angles in question fairly accurately. The midpoint of the fore and aft extent of the proximal end of a rib, lies exactly in midlength of its corresponding neural plate. All angles were therefore measured from the geometrical centers of the neural plates. The position of the rib below the distal edge of a costal plate can usually be determined by the lateral bulge in the course of the marginal line above the rib.

TABLE 2.—Angles between the ribs and the longitudinal axis of the shell, measured for the first 6 ribs in various species of *Aspideretes*. In order to compensate partially for individual variation, possible distortions by formation pressure and the difficulty of having to rely on measurements from illustrations, the following angle groups were established: +6 (58°-62°); +5 (63°-67°); +4 (68°-72°); +3 (73°-77°); +2 (78°-82°); +1 (83°-87°); 9 (88°-92°); —1 (93°-97°); —2 (98°-102°); —3 (103°-107°); —4 (108°-112°); —5 (113°-117°); —6 (118°-122°).

Aspideretes species:	1st rib	2nd rib	3rd rib	4th rib	5th rib	6th rib
vegetus Gilmore	+6	+4	+2	+2	0	—2
singularis Hay	+5	+4	+2	+1	—1	—1
ellipticus Hay	+5	+3	+2	+1	—1	—4
annae Zangerl	+6	+4	+3	+1	—1	—4
lancensis Gilmore	+4	+1	+1	0	—1	—3
puercensis Hay	+5	+3	+1	0	—1	—3
subquadratus Lambe	+4	+3	+2	0	—1	—3
perplexus Gilmore	+3	+3	+1	0	—1	—4
superstes Russell	+5	+4	+2	0	—1	—4
grangeri Hay	+5	+2	+1	0	—2	—4
splendidus Hay	+4	+3	+1	0	—2	—4
rugosus Parks	+5	+3	+1	0	—2	—4
reesidei Gilmore	+5	+3	+2	0	—3	—4
quadratus Gilmore	+5	+3	+1	0	—4	—5
foveatus Leidy	+3	+2	0	—1	—2	—4
sagatus Hay	+5	+3	0	—1	—3	—5
beecheri Hay	+4	+2	0	—1	—4	—6

2. None of the ribs lie within the 88°-92° class. The first ribs are bent craniad, the 5th and 6th caudad.

3. Rib no. 4 is at right angle to the main axis of the shell. The first 3 ribs are bent forward, nos. 5 and 6 backward.

4. In this group it is rib no. 3 that forms a right angle with the longitudinal axis of the body. The first 2 ribs point forward, nos. 4, 5, and 6 are bent caudad.

The fact that the ribs are bent forward in the anterior part of the carapace, backward in the rear, may be of some phylogenetic significance. Obviously such angulation aids in the enlargement of the shell in antero-laterad and postero-laterad directions, i.e., toward those regions of the shell that accommodate the retracted extremities. It appears reasonable to assume that the 4 groups, distinguished above, represent 4 different lines of dvelopment to accomplish such an enlargement of the shell.

On the basis of these angles alone it is possible to distinguish all the forms of the genus included in Table 2. In the case of *A. superstes*, where at least 2 well preserved specimens are figured (Russell 1930), both show surprisingly similar values, if obvious distortions of the shells are taken into account, by using the averages between the values of the right and left sides of the shells. The angles of *A. planus* Parks are very close to those of *A. splendidus* Hay. The validity of the former species is doubtful since all the differentiating characters given by Parks (*loc. cit.*) are well within the range of individual variation of shells of recent species.

In his morphological, systematic and phylogenetic study of the fossil soft-shell turtles, Hummel (1929) complains that far too many species of trionychid turtles have been described from the American Eocene even if all those forms are excluded which are based on insufficient material. In support of this view Hummel compares the numbers of species of the American Eocene with recent species distribution, and illustrates the great variability of the carapace plates in 5 specimens of a recent form, *Trionyx* (*Amyda*) *cartilagineus*. One of these specimens even exhibits a major character of the genus *Aspideretes*, a preneural plate.

There is hardly any doubt that the number of species described from the American Eocene is too high, and some will have to be abandoned when larger series of fossils can be examined. Hummel's argument, however, that the number of described species of the American Eocene is too high, because far fewer species of soft shell turtles are found in any comparable region of the globe at the present time, does not hold ground. To cite one instance from among the many available ones, enormous numbers of species of ammonites lived in the past but none survived to the present day. It is at least possible that the trionychid turtles reached their height of speciation in Eocene times. Hay (1908) may well have been right in saying about the Bridger Formation of Wyoming: "Emydidae abounded, and Trionychidae ran riot."

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Folliculinid Protozoa on North American Coasts

E. A. Andrews

Ciliated protozoans of the family Folliculinidae have the anatomy of the fresh water stentors but more specialized feeding apparatus, associated with their habit of dwelling in secreted tests found attached to a great variety of objects on the bottom of the sea, often near the shores but also in deep water. Since their first discovery on the Danish coast in 1781, they have been put on record as found in many European localities, in the Arctic, and Antarctic, and some parts of the Pacific, but not as yet on any coast of Africa or South America, or most of the shores of Asia. Moreover, on the North American continent they are recorded only from Rhode Island, Massachusetts, Maryland and North Carolina.

While they attach their tests or dwellings that somewhat resemble clear glass bottles (whence they have been called bottle animalcules) to some temporary substrates such as aquatic flowering plants, or sea weeds, they occur frequently upon more permanent objects such as shells both in pure sea water and in brackish waters. To be sure certain kinds are found only upon the shells of living crustaceans and others frequent the abandoned houses of some bryozoa and hydroids but in general any sort of solid seems to suffice for a substrate upon which to build and several observers have taken them on the walls of aquaria and upon glass slides suspended in the sea, notably Moebius, Sahrhage and Fauré-Fremiet.

The first notice of their attaching to the shells of oysters was that of Professor John Ryder, who found them in 1880 in Maryland waters of the Chesapeake Bay and as we subsequently found them at the same locality as well as on the oyster beds in the Severn River, it seemed that the collection of oyster shells from other localities might serve to determine a wider distribution of these infusoria.

Oysters being readily purchased and shipped, it was found that they often bore recognizable folliculinid tests on their shells, especially when not allowed to dry out.

Then, with the generous aid of zoologists in Canada and the United States, many of whom are here listed, living oysters and preserved oysters and shells were obtained from the whole range of oyster growth up from Texas to the northernmost limit in the Gulf of St. Lawrence, and even from the Pacific shores of California.

From some 27 localities, folliculinids were found on oysters and in fact but few random collections did not show folliculinids so that these protozoans may be reckoned as common members of the oyster shell community.

To emphasize the value of oyster shell examination in determining the geographical distribution of folliculinids, we have drawn up the following

summary of all the forty-five places in which they have thus far been found, with some account of their abundance and density of distribution as well as the specific determination of the nine different sorts that we at present recognize as occurring in this continent.

As about a dozen places mentioned are chiefly subdivisions of the Chesapeake near Baltimore, where folliculinids swarm on submerged aquatic plants, they may be regarded as one locality, which reduces the entire number to thirty-three, of which twenty-seven are found on oyster shells— a very large majority of the whole.

At present then, our actual knowledge of the width of distribution rests largely upon oyster-shell observations.

However, it is not to be assumed that folliculinids have any preference for oyster shells. As seen in the following lists where other shells occur with or without oyster shells, folliculinids are found upon these also. On such muddy and sandy bottoms as those of branches of the Chesapeake, oyster shells may be the only solids folliculinids can find to attach their tests to and thus the oyster bed becomes an addition to the rocky and sea-weed habitats often frequented by folliculinids.

From the present record we may predict that these protozoans will be found in some fresh waters of North America, since they have been recorded from fresh waters in England, France and Switzerland and even South America. Some, like such jellyfish as Craspedacusta, may have succeeded in penetrating from the sea through brackish waters to fresh ponds and streams.

In the following detailed enumeration of all the known places where folliculinids have been taken in North America, we proceed from north down the Atlantic coast into the Gulf of Mexico and then out to California's Pacific shores where, hitherto, no folliculinids had been recorded.

Geographical Distribution

GULF OF ST. LAWRENCE, CANADA

1. From the most northerly known American oyster beds, at Bideford River, Malpegue Bay area, the north shore of Prince Edward Island, nine out of 20 oyster shells bore a small form of *Metafolliculina andrewsi* ,in rather dense settlements of 6 or 7 up to 30, with often only 10 to 20 on a shell: 8,30/'42.

2. On the south side of Prince Edward Island, near Charlottetown, at Hillsborough River, each of six small oyster shells bore *Parafolliculina violacea* and two of them bore also *Metafolliculina andrewsi.* The first species stood in scattered settlements of few up to more than 100 with, sometimes, on a single shell 2-5 settlements, which in the latter case might be made up of 100, 50, 20, 20, and 5 individuals; the second species occurred in rather dense settlements of about a dozen: 9,25/'42.

3. On the north coast of Nova Scotia, from Malagash Basin, off Tatama-

gouche Bay, only one out of ten small oysters bore two individuals of a small form of *Metafolliculina andrewsi,* one on each of the opposite valves: 9,13/'42.

ATLANTIC COAST OF THE UNITED STATES

COAST OF MAINE

4. The hermit crab, *Pagurus pubescens* Kroyer, taken in Frenchman's Bay in 1839-40 by Professor E. G. Reinhard, carries as commensals, a folliculinid which we deem to be a form of *Platyfolliculina* Hadzi similar to his *P. sahrhageana* and name *P. paguri.*

5. While living oysters are rare in Maine, eight living and seven shells taken near Booth Bay Harbor bore *Parafolliculina violacea* upon four of the fifteen objects, in scattered groups of 32-50.

One shell bore an aggregate of 200 on an area of 90 by 15 mm., another had settlements of 300 on one valve and 10 on the other valve. In an area of 3 by 20 mm. across the opening between gaping valves there were on the one side 15 and on the other 20; as if they all had settled with reference to the others: 10,14/'42.

This species occurred upon the following objects from that same locality. One out of six shells of *Mytilus edulis* bore little groups of 4 or 5 in one place and 13 in another. Each of five shells of *Littorina littorea* bore the same in groups of, on each, 3, 13, 4 or 5, 30 and 40. One out of five bits of stone bore the same as 50 scattered individuals.

Also, *Lagotia viridis* occurred upon three out of 18 shells and valves of *Cypris islandica* and upon 15 of 30 giant valves of *Pecten megellandica,* where they stood in numbers from few to many hundred on the inner and sometimes on the outer surfaces with density from 5 or 6 up to 200 per six hundred square mm.

MASSACHUSETTS COAST

6. From Waquoit Bay on the south shore of Cape Cod peninsula, 11 out of 22 empty valves of oysters bore folliculinids; one bore *Parafolliculina violacea* and six *Metafolliculina andrewsi;* and four both of these species: 8,19/'42.

The former occurred generally as small settlements of few individuals both upon the shell itself and upon the encrusting bryozoa, but with one community of upward of forty. The latter occurred as generally small settlements of few scattered individuals, but sometimes with dense clusters of a few in the midst of large groups running from 20 to 500 individuals, as if there had been some central attraction in settling. One shell had a settlement of 25 in one place and 30 in another; another shell had 25 and 60.

In that same region both these species were found upon the shells of two of three *Mya arenaria,* each of two *Venus mercenaria* and upon one of five Anomia. *Mya* bore *Metafolliculina andrewsi* as settlement of several hundred in a depressed area of 25 by 50 mm. Venus bore colonies of both species along etched out grooves of the outer surface as well as upon, and underneath, encrusting bryozoa. Also on the inner face of one shell there was a large set-

tlement of several hundred in which small groups of *M. andrewsi* stood in the midst of the more numerous *P. violacea*. The Anomia held a commingled settlement of both species along with Perophora in a depression near the hinge.

7. At Woods Hole, Mass., some 7 or 8 species of folliculinids have been taken on algae, hydroids and walls of aquaria, shells and limuli, but as yet not on oyster shells. Hydroids collected there in 1888 and studied by W. K. Brooks, were found much later (Andrews 1921) to bear *Lagotia viridis* (*Semifolliculina boecki*) and what has since proved to be *Parafolliculina violacea* (Andrews 1942). The former was studied there in 1914 by Elmer J. Lund without publication and by V. Dewey in 1939 under the terms *F. aculeata, F. elegans* and *F. viridis,* which we combine as *Lagotia viridis*.

In 1915 Dons observed his *Lagotia spirorbis* from some part of the coast of North America, which may well have been Woods Hole. But Fremiet studying there in 1929 mentioned in 1936 that he found there in aquaria *Metafolliculina andrewsi* (*Folliculinopsis producta*), *Parafolliculina amphora, Lagotia viridis* (*F. elegans*) and *Lagotia simplex* (*F. simplex*). All these folliculinids were observed only in the summer seasons and little is recorded as to frequency of occurrence or modes of distribution over substrates. In summer '43 aquaria revealed what seems *Metafolliculina longicollis* Hadzi.

In the summer and autumn 1942, limuli at Woods Hole carried with them *Metafolliculina andrewsi* and *Parafolliculina violacea* on shells of *Crepidula fornicata* attached to the limulus, and also on the egg capsules of Bdelloura fastened to the gill plates of limuli. In this last situation there were also many hypercommensal folliculinids that we regard as representing a new genus and species to be called *Pseudoparafolliculina portitor*. This was first observed by Leidy in 1850 and by Gissler in 1882.

RHODE ISLAND COAST

8. At Newport, Rhode Island, in July 1859, Leidy found the first folliculinid recogniged in America, attached to *Anomia serpula* on clam shells dredged by Col. Powel. These he called *Freyia americana,* but later, according to Ryder, considered to be the same as the European *Folliculina ampulla,* but we identify his form as *Lagotia viridis*.

NEW YORK STATE

Long Island Sound

9. About fifty oyster shells taken in deep water (18-70 fathoms) near Gardiners Island, bore few tests of *Metafolliculina andrewsi* and *Lagotia viridis*. *Parafolliculina violacea* stood both scattered and in colonies, 4-6 to the square mm.; in one colony 2 close together facing alike: 2,13/'42.

10. At Oyster Bay only six of fifty shells bore *P. violacea* in groups of half a dozen in the furrows between the ridges, 2-4 to the square mm., with a few groups of 3 close together and facing alike: 3,4/'42.

11. Near West Sayville, South Bay, on the south coast of Long Island,

limuli taken by the Bluepoints Company bore the hypercommensal *Pseudoparafolliculina portitor:* 12, /'42.

COAST OF NEW JERSEY

Delaware Bay

12. Near Bivalve, N. J., 40 out of 55 small shells bore what we regard as *Folliculina ampulla* Mueller, from one to 30 individuals to a shell, 300 in all. A shell of 2 inches bore 15 at the rate of 3 to a square mm. Limuli from near Cape May bore as hypercommensal *Pseudoparafolliculina portitor* in the summers of 1942 and 1943.

CHESAPEAKE BAY

Maryland Waters

13. Far up Middle River at Clark's Point and in the branch Frogmorter and near the buoy at the mouth of Middle River, *Metafolliculina andrewsi* and *Parafolliculina amphora* were very abundant upon elodea, zostera and potamogeton: 9,27/'41, while some were still found: 11,22/'41. However none were there on abundant plants: 5,23/'42, 6,25/'42 and 7,26/'42.

14. Along Bowley's Neck, just above the mouth of Middle River, at "Miami Beach" and south of it, elodea and zostera bore *Metafolliculina andrewsi* and *Parafolliculina amphora:* 9,21 and 10,1/'41.

15. Back River is polluted and nearly devoid of the usual aquatic shore vegetation of Chesapeake Branches, but near its mouth the small branch "Long Creek" revealed some *Metafolliculina andrewsi* and *Parafolliculina amphora* on elodea and the submerged fallen leaves of willow tree: 11,2/'42.

16. At the mouth of the Patapsco River, on the north shore of Bodkin Creek, *Metafolliculina andrewsi* and *Parafolliculina amphora* were found on elodea: 10,4/'16.

17. Elodea in Magothy River bore *M. andrewsi* and *P. amphora* near its head: 8,13/'21, and at its mouth 8,23/'21.

18. Elodea in the Little Magothy, bore *M. andrewsi* and *P. amphora* in 1921.

19. The branch "Deep Creek" of White River showed *M. andrewsi* and *P. amphora* on elodea in 1913.

20. Severn River Whitneys Landing on elodea 10,9/'43.

21. Above the White Sands: 10,8/'22 and 10,9/'43.

22. At "White Sands" elodea bore abundant *M. andrewsi* and *P. amphora:* 6,27/'12 to 9,1/'12; and again 7,19 to 8,26/'14 and the summer time of 1921; abundant upon Potamogeton 9,10/'43 and 10,3 and 9, /'43.

23. In the western part of Round Bay, on the beds between St. Helena

Island and Sherwood Forest many oyster shells bore not only *M. andrewsi* and *P. amphora* but a new form we think to be *Folliculina ampulla* Mueller as interpreted by Dons: 12/'41. And of 48 shells 29 held folliculinids; 20 being *F. ampulla,* 7 *M. andrewsi* and 4 *P. amphora,* there being some shells with more than one species: 3,17/'42.

On some shells the *F. ampulla* stood in large groups, ¾ mm. apart in the groups. One shell had only one small group of *M. andrewsi,* another entire shell had but 20 scattered *P. amphora.*

24. On the East side of Round Bay, off Eagles Nest Point, 13 out of 27 shells bore folliculinids; one bore only 5 or 6 *M. andrewsi,* eight *P. amphora* (100 in one colony), and four *F. ampulla,* as one only on each: 4,27/'42. Only 3 out of 42 shells bore old tests of *F. ampulla:* 6,27/'42.

Again, out of 75 oysters only 15 bore folliculinids: eight bore only *M. andrewsi* in groups of few to 30 near the edges of the shell or else in depressions, and only two *F. ampulla,* standing few in a group, while five bore both those species: 8,15/'42.

25. In Chases Creek, certain areas of elodea and potamogeton supported vast numbers of *Metafolliculina andrewsi* and *Parafolliculina amphora* during the months of July and August, appearing and disappearing suddenly and at different dates in 1912, 1913, and 1914 (see Andrews, 1914 and 1915). Many of both species were found again on limited areas of elodea 8,29/'41 and 9,10/'42.

26. On the north bank of Weems Creek above the bridge, in West Annapolis *M. andrewsi* was found in considerable numbers on leaves of potamogeton with seed heads: 7,28/'43.

27. In Back Creek, below Annapolis, elodea and potamogeton bore both *M. andrewsi* and *P. amphora* in the summer of 1912.

28. Below the Severn at Bay Ridge the nearly closed off Oglethorpe Lake was thickly set with elodea bearing abundant *M. andrewsi* and *P. amphora:* 7,18/'23.

29. Below that a brackish creek to the northeast of Arundel on the Bay contained both *M. andrewsi* and *P. amphora:* 7,25/'19.

30. Off Solomons Island Laboratory, at the mouth of the Patuxent, 9 out of 14 oyster shells supported folliculinids; 7 of them bore *E. ampulla* and 3 bore *P. amphora;* the greatest number on one shell being 7 of the two species combined: 4,28/'42.

31. In the harbor at St. Jerome, St. Mary's County, back in 1880 Ryder found *Metafolliculina andrewsi* (*Freia producta* Wright) on oyster shells. We found most all the stones and oyster shells in parts of the harbor bore very many *M. andrewsi* as well as *P. amphora,* yet shells from five feet depths off the mouth of the harbor showed none: 8,23/'22. Later we found also *F. ampulla* when the two other species were widely scattered over the four inch white valves generally avoiding areas with bryozoa, with a density of rarely

five or six, often but two and often but a fraction of one to the square mm.: 3,3/'23.

32. From Tangied Sound, on the Eastern side of the Chesapeake, of sixteen oyster shells only one bore *M. andrewsi* and two bore *P. violacea.* Both species were few and scattered: 3,19/'42.

Virginia Waters

33. From the oyster beds near Spe Point at the mouth of York River, of 15 shells 10 bore folliculinids, namely, five *P. violacea,* 5 *F. ampulla,* 2 *M. andrewsi* and one *P. amphora,* some bearing more than one species. One shell bore two *M. andrewsi,* one bore 125 *F. ampulla* standing at the rate of 1/8 to the sq. mm. in certain areas, two shells bore *P. violacea,* 8 on one and 30 on the other, distributed at the rate of 1/8 to the sq. mm.: 4,27/'42.

ATLANTIC COAST OF VIRGINIA

34. Of 6 big oysters from Toms Cove one showed a test of *P. amphora:* 3,7/'42. Of 12 oysters sold in Baltimore as from Toms Cove, Chincoteague Bay, one bore a dozen *M. andrewsi* and one bore two tests of *P. violacea:* 4,18/'42.

35. One of 23 Burton Bay oysters from Wachapreague bore four *P. violacea:* 5,4/'42.

36. Of 26 one to two inch Hog Island Bay oysters from Willis Wharf, one only bore a single *Folliculina ampulla:* 4,23/'42.

ATLANTIC COAST OF NORTH CAROLINA

37. At Beaufort, N. C., Visscher found *P. Violacea* on shell of Pinna: 6,24/'24. Of 27 oyster shells from Beaufort nine bore folliculinids, namely, *P. violacea,* on 6, *P. amphora* on 6, *M. andrewsi* on 2, some shells bearing more than one species. Two shells bore 97 individuals but most bore but 1-3 specimens. In all there were 117 individuals, 105 *P. violacea,* 10 *P. amphora* and but 2 *M. andrewsi:* 5,27/'42.

GULF OF MEXICO

ELORIDA

38. Of 30 small "coon" oysters, from Cedar Keys, 19 bore *Metafolliculina andrewsi* with 2-6 scattered settlements on a shell, containing each from a few up to 150 individuals. One shell had a settlement of 150 in one place and another of 20 elsewhere. There were some linear colonies of 20 in grooves of the shell where the lamellae overhung or stood up in ridges: 8,15/'42.

39. From Santa Rosa Sound, near Pensacola, 13 2-3 inch flat valves of oyster shells bore *M. andrewsi* on only 5, in settlements of few to more than 50 with some close clusters as well as scattered individuals; and one of the five bore a few *P. amphora:* 9,11/'42.

LOUISIANA

40. From Grand Pass, Louisiana, out of 10 shucked oyster shells only two bore *M. andrewsi* in small settlements of 16-20 scattered individuals: 7,31/'42.

41. Two heavy 4 and 5 inch oysters covered with grey growths, soft bryozoa, etc., taken in 3½ feet of water near Middle Bank, but not on a hard reef, in Grand Lake, Louisiana, bore on a small clear area on one several dozen, occupied tests of *Metafolliculina andrewsi* and on the other but a few old tests of the same species: early September 1942.

TEXAS

42. Near Rockport, Texas, oyster shells from beds near Copano Causeway, near Miller's Wharf, Aransas Bay, bore *M. andrewsi* on only 2 out of 11 shells: 6,19/'42 (salinity 20.02).

43. Oyster shells from Rattlesnake Point, Copano Bay bore *M. andrewsi* on each of the 9 shells and a few of these shells also bore scattered *P. amphora:* 6,18/'42 (salinity 18.8).

PACIFIC OCEAN

CALIFORNIA

44. At Corona Del Mar, Balboa Harbor, California, 4 little shells and fragments of the native oyster bore on two only small folliculinids which we regard as a form of *Lagotia viridis* Dons: 5,16/'42.

45. From Cuyler's Harbor, San Miguel Island, five out of six hermit crabs, *Pagurus hemphilli,* bore small folliculinids scattered on the posterior upper surface of the abdomen: 7,'39. We think these are *Lagotia simplex* Dons.

ACKNOWLEDGMENTS

List of persons to whom I am indebted for materials: Dr. C. J. Kerswill, Prince Edward Island Biological Laboratory, Canada; Professor T. H. Morgan, California Institute of Technology; Professor G. E. MacGinitie, California Institute of Technology; Professor R. V. Truitt, University of Maryland, College Park, Md; Professor T. C. Nelson, Rutgers University, New Brunswick, N. J.; Professor C. L. Newcombe, William & Mary College, Williamsburg, Va.; Dr. H. F. Prytherch, Director, U. S. Marine Laboratory, Beaufort, N. C.; Dr. Gordon Gunter, Marine Biologist, Game, Fish and Oyster Commission, Rockport, Texas; Dr. E. W. Berger, State Plant Board, Gainesville, Florida; Professor R. P. Cowles, Johns Hopkins University; Dr. Chas. E. Brambel, Johns Hopkins University; David H. Wallace, Administrative Assistant, Department of Tidewater Fisheries, Annapolis, Md.; Mr. Grinnell Huges, Gainesville, Florida; Dr. M. H. Bidwell, Bacteriologist, N. Y. State Conservation Department, Freeport, L. I., N. Y.; Chas. Woolley, Manager, J. & J. W. Elsworth Co., Greenport, L. I.; Supply Department Companies: Woods Hole, Mass., North Carolina, Louisiana.

JOHNS HOPKINS UNIVERSITY,
BALTIMORE, MD.

Studies on Monogenetic Trematodes

XI. Dactylogyridae from Algonquin Park Fishes*

John D. Mizelle and Sr. M. Angela Donahue, R.S.M.

The present material consisting of twenty vials containing gills and monogenetic trematodes, was collected in 1939 from one stream and several lakes in Algonquin Park, Ontario, Canada, by Dr. R. V. Bangham of the College of Wooster, Wooster, Ohio. The habitats and hosts from which they were obtained are as follows: 1) Costello Creek: finescale dace (*Pfrille neogaea*); 2) Proulx Lake: brown bullhead (*Ameiurus nebulosus*), common shiner (*Notropis cornutus*), yellow perch (*Perca flavescens*), pumpkinseed sunfish (*Lepomis gibbosus*); 3) Opeongo Lake: smallmouth bass (*Micropterus dolomieu*), black bullhead (*Ameiurus melas*), yellow perch (*Perca flavescens*), pumpkinseed sunfish (*Lepomis gibbosus*); 4) Dixon Lake: brown bullhead (*Ameiurus nebulosus*); 5) Brewer Lake: pumpkinseed sunfish (*Lepomis gibbosus*); 6) Smoke Lake: brown bullhead (*Ameiurus nebulosus*); 7) Costello Lake: pumpkinseed sunfish (*Lepomis gibbosus*); 8) Long Lake: yellow perch (*Perca flavescens*), pumpkinseed sunfish (*Lepomis gibbosus*).

The parasites in about one-half of the vials were preserved in five per cent formalin and the rest were in Bouin's fluid. From the condition of the specimens it is clear that none of them was relaxed before fixation with either of the solutions. Many more trematodes were found in the formalin preservative than in the Bouin's fluid. This supports the contention of Mizelle (1938a) that Bouin's fluid is an unsatisfactory fixative and preservative for these parasites. No parasites were found in two of the vials, namely, 1) one for the smallmouth bass from Opeongo Lake and 2) one from the fine-scale dace from Costello Creek.

The material containing the parasites was poured into Syracuse watch glasses and diluted and decanted until clear enough for reliable examination with a widefield binocular microscope. Bouin's-fixed material was washed in water for several hours prior to examination in order to remove as much of the yellow color as possible. Many parasites were found free from the gill material and were isolated with ease, whereas others were so entangled in mucus and branchial tissue that it was necessary to tease them free with dissecting needles before isolation and mounting. Permanent mounts were made by selecting the parasites individually with a capillary pipette equipped with a rubber bulb, and transferring them to a drop of glycerin-gelatin medium which had been allowed to solidify on a glass slide. A cover glass was placed

* Contribution from the Department of Biology, University of Notre Dame, Notre Dame, Indiana.

on the preparation, the slide was heated gently, and the medium melted and spread evenly between the slide and the cover glass. The medium solidified on cooling and a permanent mount was thus produced. Three hundred and twenty-five slides were prepared in this manner. They contained three hundred and fifty trematodes for the entire collection. Measurements were made of the body length, the greatest body width, the diameter of the pharynx, the length of the cirrus and accessory piece, the haptoral length and width, the length of the anterior and posterior (or the ventral and dorsal) bars, the length and base width of the ventral and dorsal (or anterior and posterior) anchors, and the hook lengths. The body length measurements were done with the aid of a low-power objective; body width and haptor length and width were done utilizing a high-dry objective; and an oil immersion objective was utilized in the determination of all the other measurements. Each curved structure was measured as a straight line extending between the two most distant parts of same. The accompanying figures were made at the same magnification and with the aid of a camera lucida.

Recently the authors were impressed by Hoff's (1943) comments on improving taxonomic literature. This author appeals for 1) minute descriptions which will stand the test of time . . . so often punctuated by additions of species to various genera; 2) use of a number of type specimens instead of a single one in order that limits of morphological variation may be known; 3) utilization of clear concise descriptive terms; and 4) citation of authors of generic changes so that pertinent references may be examined with greater dispatch. The present authors heartily agree with Hoff's suggestions and regret that lack of regard for them in the field of North American fresh-water Gyrodactyloidea has resulted in many telescoped descriptions, many errors, and several synonyms. There is little or no excuse for species description from a single specimen when plenty are available. The senior author of the present paper has always endeavored to use twenty specimens in his descriptions and redescriptions whenever possible and as many as available when fewer than twenty were forthcoming. It is regrettable that only one specimen was available for each of several of the descriptions and redescriptions herein. Additional information concerning these will be made if and when more material is obtained.

Information in quotation marks, occurring in regard to previously described species, means that it was taken from the source indicated and is being used in a comparative manner.

The genus *Neodactylogyrus* Price, 1938, is rejected because the presence of the vestigial ventral bar required for assignment of species, thereto, is differentially developed, not always visible in fixed specimens, and results in unnecessary synonymy. Possibly another character would better serve for generic fission.

The authors wish to express their appreciation to Dr. R. V. Bangham of the College of Wooster, Wooster, Ohio, for the collection and permission to examine the material on which this paper is based.

Actinocleidus gibbosus n. sp.

Pl. 1, Figs. 34-42

Host and Locality.—Pumpkinseed Sunfish *Lepomis gibbosus,* Opeongo Lake in Algonquin Park, Ontario, Canada.

Specimens Studied.—One.

Type Specimen.—Type, Univ. of Notre Dame, Notre Dame, Indiana.

Description.—Small dactylogyrid 0.252 mm. long by 0.039 mm. in greatest body width and with a thin smooth cuticle. Peduncle of moderate size, haptor subcircular in outline and 0.052 mm. wide by 0.043 mm. long. Haptoral bars dissimilar and each possessing a pair of structures which articulates the bars together (Pl. 1, Figs. 36, 37). Anterior bar strongly bent posteriorly in the midportion and with rounded ends and subterminal notches; anterior bar length 0.038 mm. Posterior bar stout, with ends and the moderate-sized shoulders posteriorly developed; length 0.020 mm. Anchors with shafts (hollow) and points which unite without the formation of an angle. Anchor points with recurved tips. Anterior anchors slightly bifurcate, superficial root prominent, deep root small; anterior anchor length 0.036 mm., greatest width of base 0.011 mm. Posterior anchor base with a vestigial deep root, superficial root of moderate size; posterior anchor length 0.031 mm., greatest width of base 0.008 mm. Hooks fourteen in number and normal in arrangement (Mizelle 1938a). Hook bases ovate, shafts slender and solid (Pl. 1, Fig. 42); hook lengths 0.011-0.015 mm. Eye spots four, members of the posterior pair strikingly larger and closer together than those of the anterior pair. Pharynx ovate (vertically elongate) in side view and 0.011 mm. by 0.014 mm. Cephalic lobes small, head organs poorly developed. Copulatory complex composed of a basally articulate cirrus and accessory piece (Pl. 1, Figs. 40, 41). Each of these structures has a relatively large base which unites with a tapered and curved shaft; cirrus length 0.030 mm., accessory piece length 0.022 mm. Vagina located on left margin near the midlength of the body and provided with a lightly chitinized canal. Seminal vesicle, seminal receptacle, and prostates not observed. Vitellaria moderately developed and extend to the peduncle.

This species possesses the haptoral armament characteristic of the genus *Actinocleidus,* Mueller, 1937. The cirrus is similar in shape to that of *A. flagellatus* Mizelle and Seamster, 1939, but the accessory piece is very different from that of any other member of the genus.

Actinocleidus incus n. sp.

Pl. 1, Figs. 43-49

Host and Locality.—Pumpkinseed Sunfish *Lepomis gibbosus,* Opeongo Lake in Algonquin Park, Ontario, Canada.

Specimens Studied.—One.

Type Specimen.—Type, Univ. of Notre Dame, Notre Dame, Indiana.

Description.—Small dactylogyrid 0.270 mm. long by 0.041 mm. wide (greatest body width) with a smooth thin cuticle. Peduncle of moderate size,

haptor subcircular in dorsal view. Haptor width 0.073 mm. Haptoral bars dissimilar, individual, and with well-defined articulating structures by which they unite with each other (Pl. 1, Figs. 44, 46). Anterior bar bent posteriorly in the middle and with subterminal notches and rounded ends; anterior bar length 0.041 mm. Posterior bar developed posteriorly and with the ends directed outwardly, shoulders large; posterior bar length 0.027 mm. Anchors similar in shape and size, anchor shafts hollow, tips of anchor points moderately recurved (Pl. 1, Figs. 43, 45). Anterior anchor bases notched; superficial root prominent, deep root small. Anterior anchor length 0.032 mm., width (greatest) of base 0.011 mm. Posterior anchor base with a deep cleft which separates the two roots. Posterior anchor length 0.031 mm., greatest width of base 0.008 mm. Wings double and prominent on members of each pair of anchors. Hooks normal in number and arrangement (Mizelle 1938a), subequal in length, and each consisting of an oval base, a slender solid shaft, a sickle-shaped termination, and an opposable piece (Pl. 1, Fig. 49). Hook lengths 0.012-0.014 mm. Eye spots four in number; members of the posterior pair several times larger than those of the anterior pair and contiguous in the single specimen available for this description. Cephalic lobes moderate, head organs well defined, cephalic area anterior to eye spots extensive. Pharynx ovate, longitudinally elongate, transverse diameter 0.016 mm. Gonads ovate in outline (dorsal view), tandem in arrangement, and subequal in size; testis posterior. Copulatory complex consisting of a doubly recurved cirrus and an accessory piece which articulate with each other basally (Pl. 1, Figs. 47, 48). Cirrus with a moderate-sized base which tapers toward the shaft. Accessory piece doubly curved and provided with a process terminally which unites with the shaft at approximately 90 degrees. Cirrus length 0.022 mm., accessory piece length 0.017 mm. Vagina, seminal receptacle, seminal vesicle, and prostate glands not observed. Vitellaria moderate in development and extending from the posterior border of the pharynx into the peduncle.

While this species is similar to other members of the genus in the nature of the haptoral armament it is distinctly different from all of them in the possession of the characteristic cirrus and an accessory piece with a terminal "bar" structure.

ACTINOCLEIDUS OCULATUS (Mueller, 1934) Mueller, 1937

Pl. 1, Figs. 9-17

Synonym.—Cleidodiscus oculatus Mueller, 1934.

Host and Localities.—Pumpkinseed sunfish *Lepomis gibbosus;* Long and Opeongo Lakes in Algonquin Park, Ontario, Canada.

Previously Reported Hosts and Localities.—Lepomis gibbosus, State Fish Hatchery Reservoir, Constantia, N. Y. (Mueller 1934) and Syracuse, N. Y. (Mueller 1936). "Sunfish" Cross Lake, N. Y. (Mueller 1936). Bluegill Sunfish *Lepomis macrochirus,* Baton Rouge, La. (Summers and Bennett 1938).

Specimens Studied.—Fourteen.

Redescription.—Small, smooth, thin-cuticled dactylogyrids measuring

0.265 mm. (0.234-0.396 mm.) long by 0.052 mm. (0.038-0.086 mm.) wide (greatest body width) "Length about 0.240 mm., width 0.054 mm." Eye spots of the posterior pair larger and closer together (infrequently united) than members of the anterior pair. "The eyes are large, the anterior and posterior pairs about equi-distant." Cephalic lobes poorly defined, head organs moderately developed. Pharynx circular to ovate in outline (dorsal view) and 0.015 mm. (0.012-0.018 mm.) in transverse diameter "0.017 mm." Peduncle short to moderate in length, haptor subcircular in outline; haptor width 0.063 mm. (0.056-0.073 mm.), length 0.051 mm. (0.043-0.056 mm.). Anterior bar bent posteriorly in midportion, with rounded ends, and subterminal notches; length 0.045 mm. (0.036-0.056 mm.). Posterior bar with outwardly directed ends and shoulders of variable size, distinctly different from the figure in Mueller's descriptions (Pl. 1, Fig. 12 and Mueller 1934, Pl. 47, Fig. 5, 1936, Pl. 12, Fig. 5). Posterior bar length 0.026 mm. (0.021-0.029 mm.). Both bars with individual and well-defined articulating surfaces which were originally figured as fused together (Pl. 1, Figs. 10, 12 and Mueller 1934, Pl. 47, Fig. 5 and 1936, Pl. 12. Fig. 5). Anchors similar to those in the original description except that the posterior anchors are 1) slightly longer than the anterior anchors, 2) the anchor shafts are hollow instead of solid, 3) the distal portions of the anchor points are recurved, and 4) the bases of the anterior anchors are generally distinctly bifurcate (Pl. 1, Figs. 9, 11 and Mueller 1936, Pl. 12, Fig. 5). Anterior anchor length 0.035 mm. (0.032-0.036 mm.), greatest width of base 0.011 mm. (0.009-0.013 mm.), posterior anchor length 0.036 mm. (0.034-0.038 mm.), greatest width of base 0.010 mm. (0.009-0.011 mm.). "Greatest length of a hook, not following the curve, 0.038 mm." Hooks subequal in length, normal in arrangement, and as figured in the original description except that each is provided with a distinct opposable piece and a posterior projection which arises from the convex surface of the sickle-shaped termination (Pl. 1, Fig. 13). Hook lengths 0.010-0.016 mm. Gonads ovoid in outline (dorsal view), tandem in arrangement, subequal in size, and located in the posterior half of the body; ovary anterior. Vagina sinistral and situated near the midportion of the body; seminal receptacle chitinized and pyriform in outline. Copulatory complex composed of a cirrus and accessory piece as figured by Mueller but with the accessory piece consistently bifurcate (Pl. 1, Figs. 14, 16 and Mueller 1936 Pl. 14, Fig. 21). Cirrus length 0.035 mm. (0.032-0.038 mm.) "0.037.," accessory piece length 0.026 mm. (0.023-0.031 mm.). Vitellaria moderately developed, extending from the pharynx to the peduncle and often scanty in the area anterior to the copulatory complex.

Actinocleidus recurvatus n. sp.

Pl. 1, Figs. 50-61

Host and Localities.—Pumpkinseed Sunfish *Lepomis gibbosus;* Costello, Long, Opeongo, and Proulx Lakes in Algonquin Park, Ontario, Canada.

Specimens Studied.—Four.

Type Specimens.—Cotypes, Univ. of Notre Dame, Notre Dame, Indiana.

Description.—Small dactylogyrids 0.261 mm. (0.180 0.324 mm.) long by

0.065 mm. (0.043-0.077 mm.) wide (greatest body width), with a thin and smooth cuticle. Peduncle short to elongate depending on the state of contraction during fixation. Haptor subcircular in dorsal view and 0.062 mm. (0.056-0.066 mm.) wide by 0.047 mm. (0.043-0.052 mm.) long. Haptoral bars dissimilar, individual, and articulate with each other by means of a pair of well-defined structures on the posterior side of the anterior bar and a corresponding pair of these structures on the anterior side of the posterior bar (Pl. 1, Figs. 58, 59). Anterior bar bent posteriorly in the midportion and 0.038 mm. (0.029-0.045 mm.) long. Posterior bar with a rough or serrate anterior margin, ends developed in a posterior manner, and possessing conspicuous shoulders; posterior bar length 0.028 mm. (0.025-0.031 mm.). Anchors similar in size and shape, and with hollow shafts and points . . . tips of latter recurved; anchor wings low and often inconspicuous (Pl. 1, Figs. 50-52). Anterior anchor bases slightly bifurcate, superficial root much larger than deep root; anterior anchor length 0.036 mm. (0.034-0.040 mm.), greatest width of bases 0.013 mm. (0.012-0.014 mm.). Posterior anchor bases with only a suggestion of a bifurcation, deep roots vestigial; posterior anchor length 0.042 mm. (0.039-0.045 mm.), greatest width of bases 0.012 mm. (0.009-0.014 mm.). Hooks fourteen in number, of characteristic arrangement (Mizelle 1938a), subequal in length in a given specimen, and each consisting of an ovate to elongate-ovate base, a relatively long slender shaft, a sickle-shaped termination, and a well-defined opposable piece (Pl. 1, Figs. 53-55). The hook bases often appear transparent in mounted material giving the impression that they are absent. Posteriorly directed projection on the convex surface of the sickle-shaped termination frequently inconspicuous. Hook lengths 0.012-0.018 mm. Eye spots four, with members of the posterior pair much larger and closer together than those of the anterior pair. Cephalic lobes rounded, head organs numerous. Pharynx outline circular to ovate in dorsal view and 0.013 mm. (0.009-0.018 mm.) in transverse diameter. Gonads tandem in arrangement; ovary ovate and situated anterior to the slightly smaller and more elongate testis. Copulatory complex consisting of a basally articulate cirrus and a short accessory piece (Pl. 1, Figs. 60, 61). Cirrus base comparatively large, cirrus shaft curved and directed toward the curved and pointed accessory piece which articulates with the cirrus near the origin of the cirrus shaft. Cirrus length 0.018 mm. (0.015-0.022 mm.), accessory piece length 0.010 mm. (0.009-0.011 mm.). Vagina sinistral, situated near the body midportion, and continuous with a highly chitinized vaginal tube of characteristic shape (Pl. 1, Figs. 56, 57). Seminal vesicle small; seminal receptacle, and prostates not observed. Vitellaria moderate to well developed and often scanty in the area between the copulatory complex and pharynx.

This species is apparently very closely related morphologically to *A. subtriangularis* Mizelle and Jaskoski, 1942, in regard to the shape of the cirrus and the haptoral hooks but possesses haptoral bars and anchors which are very similar to those of *A. brevicirrus* Mizelle and Jaskoski, 1942. The vaginal tube is different from that of any other member of the genus and it together with the somewhat variable copulatory complex serves as a highly diagnostic character.

Actinocleidus scapularis n. sp.

Pl. 1, Figs. 1-8

Host and Locality.—Pumpkinseed Sunfish *Lepomis gibbosus,* Opeongo Lake in Algonquin Park, Ontario, Canada.

Specimens Studied.—One.

Type Specimens.—Type, Univ. of Notre Dame, Notre Dame, Indiana.

Description.—Small dactylogyrid species 0.180 mm. long by 0.060 mm. wide (greatest width) with a thin smooth cuticle. Peduncle of moderate dimensions, haptor subcircular in dorsal outline. Haptor width 0.054 mm., length 0.045 mm. Haptoral bars dissimilar in shape, individual, and with well-developed articulations by which they unite with each other (Pl. 1, Figs. 2, 4). Anterior bar of the usual *Actinocleidus* type with a posterior bend in the mid-portion and rounded ends provided with subterminal notches on the posterior border, length 0.041 mm. Posterior bar with posteriorly developed outwardly directed ends, moderately large shoulders, and a rough or serrate anterior margin, length 0.025 mm. Anchors with well-developed wings (posterior higher), evenly curved hollow shafts, and with tips of the anchor points recurved (Pl. 1, Figs. 1, 3). Each anterior anchor base is differentiated to form a conspicuous superficial root and a small deep root. Anterior anchor length 0.032 mm., greatest width of base 0.010 mm. Posterior anchors with a poorly defined separation of the moderate-sized superficial root and the vestigial deep root. Posterior anchor length 0.036 mm., greatest width of base 0.011 mm. Hooks normal in number and arrangement (Mizelle 1938a), subequal in length, and each composed of a small oval base, a slender solid shaft, a sickle-shaped termination, and an opposable piece (Pl. 1, Fig. 7). A comparatively short posteriorly projecting structure arising from the convex surface of the sickle-shaped termination is present on each hook. Hook lengths 0.012-0.015 mm. Eye spots four in number, members of the posterior pair much larger (3 to 5X) and closer together than those of the anterior pair. Cephalic lobes small, head organs poorly developed. Pharynx subcircular in outline (dorsal) and 0.015 mm. in transverse diameter. Gonads situated in the posterior half of the body, ovate in outline, and with the anterior part of the slightly smaller testis overlapping the posterior margin of the ovary. Vagina *dextral,* lightly chitinized, and situated at the level of the anterior border of the ovary. Seminal receptacle, seminal vesicle, and prostates not observed. Copulatory complex composed of a short spiral (one to one and one-half turns) cirrus and a solid elongate somewhat scapular-shaped accessory piece (Pl. 1, Figs. 5, 6). Cirrus with a small base and an inflated distal portion, length 0.018 mm. Accessory piece articulated basally to the cirrus, widened distally, and with a shallow notch terminally which separates two short blunt processes; accessory piece length 0.014 mm. Vitellaria scanty and composed of small granules which terminate on the body near the origin of the peduncle.

Actinocleidus scapularis n. sp. has the general type of haptoral armament characteristic of the genus but possesses a cirrus and accessory piece which are very different and distinct from those described for other members of the genus. In addition it is the sole described species which has a dextral instead

of a sinistral vagina. This condition is most unusual but the chitinization present is normally interpreted as vaginal in nature. Immediately anterior to the vagina there exists a comparatively large triangular projection which may or may not be a part of the specimen. The scanty development of the vitellaria indicates a young specimen while the development of the gonads indicates sexual maturity.

Actinocleidus sigmoideus n. sp.

Pl. 1, Figs. 18-33

Host and Localities.—Pumpkinseed Sunfish *Lepomis gibbosus;* Costello, Long, Opeongo, and Proulx Lakes in Algonquin Park, Ontario, Canada.

Specimens Studied.—Fifteen.

Type Specimens.—Cotypes, Univ. of Notre Dame, Notre Dame, Indiana.

Description.—Small, smooth, thin-cuticled dactylogyrids, averaging 0.281 mm. (0.198-0.342 mm.) in length and 0.052 mm. (0.043-0.120 mm.) in greatest body width. Peduncle of moderate size, haptor subquadrate to ovate in outline and 0.055 mm. (0.043-0.073 mm.) wide by 0.046 mm. (0.038-0.056 mm.) long. Haptoral bars dissimilar and united with each other by conspicuous articulating structures (Pl. 1, Figs. 19, 21). Anterior bar bent posteriorly in the middle, with rounded or knobbed ends and subterminal notches; length 0.041 mm. (0.031-0.054 mm.). Posterior bar shorter, with outwardly directed rounded ends and moderate to large shoulders; length 0.030 mm. (0.021-0.034 mm). Anchors similar in shape and size, with hollow shafts and recurved hollow points (Pl. 1, Figs. 18, 20). Anterior anchor bases slightly to moderately bifurcate with superficial roots larger, deep roots vestigial. Anterior anchor length 0.033 mm. (0.027-0.039 mm.), greatest width of base 0.011 mm. (0.009-0.013 mm.). Posterior anchor length 0.035 mm. (0.030-0.041 mm.), greatest width of base 0.009 mm. (0.008-0.011 mm.). Only six pair of hooks observed with certainty. Hooks of pair number five apparently wanting . . . probably obscured by the bars. Each hook consists of a small oval base, a relatively long solid shaft, a sickle-shaped termination, and an opposable piece (Pl. 1, Figs. 22, 23). A posteriorly projecting structure arises on the convex surface of the sickle-shaped termination of each hook. Hook lengths 0.012-0.017 mm. Eye spots four in number with members of the posterior pair much larger and closer together (frequently confluent) than those of the anterior pair. Cephalic lobes moderately developed; head organs not conspicuous; pharynx circular to ovate in outline (dorsal view) and 0.016 mm. (0.012-0.018 mm.) in transverse diameter. Gonads poorly defined in fixed specimens, subequal in size, ovate in outline (longitudinally elongate) and tandem in arrangement; testis anterior. Vagina, seminal receptacle, and prostates not observed. Seminal vesicle fusiform in outline. Copulatory complex consisting of a sigmoid cirrus and an accessory piece which are articulated proximally with each other (Pl. 1, Figs. 24-33). Cirrus with a slender to moderate-sized base, a pointed termination, and a structure which passes around the cirrus shaft (in the second curve) and terminates in a minutely hooked projection directed toward the accessory piece, cirrus length 0.024 mm.

(0.018-0.034 mm.). Accessory piece bifurcate (infrequently apparently perforate) basally and attached to the cirrus base, although often it appears to attach near the origin of the cirrus shaft. Accessory piece length 0.017 mm. (0.013-0.022 mm.). Vitellaria well developed and terminate near the origin of or in the peduncle.

A. oculatus (Mueller, 1934) is apparently the closest described relative of *A. sigmoideus* n. sp. The latter is immediately distinguishable by the apparent absence of a vagina in fixed material and the presence of a smaller cirrus with its characteristic structure encircling the shaft in the distal half. *A. oculatus* possesses a distinctly chitinized seminal receptacle, a cirrus with a hooked termination, and a distally bifurcate accessory piece, all of which are foreign to *A. sigmoideus.*

CLEIDODISCUS BANGHAMI (Mueller, 1936) Mizelle, 1940

Synonyms.—Tetracleidus banghami Mueller, 1936, and *Urocleidus banghami* (Mueller, 1936) Mizelle and Hughes, 1938.

Host and Locality.—Small-Mouth Bass *Micropterus dolomieu,* Opeongo Lake in Algonquin Park, Ontario, Canada.

Previously Reported Hosts and Localities.—Micropterus dolomieu, London, Ohio (Mueller 1936) and Cove Creek, Caryville, Tenn. (Mizelle 1940). Kentucky or Spotted Bass *Micropterus punctulatus,* Cove Creek, Caryville, Tenn. (Mizelle 1940).

Specimens Studied.—Six.

The available specimens of this species were heavily impregnated with yellow stain (picric acid) imparted by the fixative. The relatively great body thickness (this is one of the larger species of Tetraonchinae) together with the yellow color and heavy development of the vitellaria permitted observation requisite only for identification. Originally this species was placed in the now-obsolete genus *Tetracleidus* Mueller, 1936, on the basis of a dextral vagina. Later (1938) Mizelle and Hughes removed it to the genus *Urocleidus* and the generic name became a synonym, in part, of *Urocleidus. C. banghami* was redescribed by Mizelle (1940) from bass hosts (*Micropterus punctulatus* and *M. dolomieu*) taken from Tennessee waters and placed in the genus *Cleidodiscus* on the basis of the morphology of the copulatory complex. It is hoped that specimens from the northern part of the United States or Canada will be available in the future so that comparisons with reference to size may be made with those contained in the redescription.

CLEIDODISCUS PRICEI Mueller, 1936

Hosts and Localities.—Brown Bullhead *Ameiurus nebulosus,* Dixon, Proulx, and Smoke Lakes; Black Bullhead *Ameiurus melas,* Opeongo Lake, all in Algonquin Park, Ontario, Canada.

Previously Reported Hosts and Localities.—Channel Catfish *Ictalurus lacustris punctatus* and Yellow Bullhead *Ameiurus natalis,* Myakka River,

Fla., Lake Okeechobee, Fla., (Mueller 1936a) and Reelfoot Lake, Ridgely, Tenn., (Mizelle and Cronin 1943). Brown Bullhead *Ameiurus nebulosus,* Myakka River, Fla., Lake Okeechobee, Fla. (Mueller 1936a), and Oneida Lake, N. Y. (Mueller 1937). Black Bullhead *Ameiurus melas,* Local Ponds and Streams near Stillwater, Okla. (Seamster 1938), Baton Rouge, La. (Summers and Bennet 1938), and Reelfoot Lake, Ridgely, Tenn., (Mizelle and Cronin 1943).

Specimens Studied.—Twenty-nine.

This species was described from Florida by Mueller in 1936 and since then has been recovered from several hosts and localities as listed above. Haptoral anchors of this species are subject to marked variation as recorded by Seamster (1938) and Mizelle and Cronin (1943). Essentially the same variations as noted by these authors have been observed in the Algonquin Park material. Particularly striking is the difference in body size for specimens of this area and that of specimens recovered from the same hosts taken from Reelfoot Lake (Tenn.). Those (nine specimens) from the black bullhead averaged 0.310 mm. (0.234-0.396 mm.) long by 0.078 mm. (0.060-0.086 mm.) wide in contrast to 0.610 mm. (0.478-0.721 mm.) and 0.091 (0.057-0.114 mm.) for length and width respectively, for Reelfoot Lake specimens from the same host. Twenty specimens from the brown bullhead measured 0.296 mm. (0.180-0.486 mm.) long by 0.079 mm. (0.051-0.112 mm.) in width, averaging somewhat smaller than those from the black bullhead host. It is unfortunate that no data are available from the brown bullhead from Reelfoot Lake for further size comparisons. Previous observations (Mizelle 1940) have tended to show that Tetraonchinae of the same species were larger in northern than in southern waters. Some of the discrepancy with regard to the above figures may be accounted for by a difference in methods of fixation but certainly this would not be sufficient to make the southern specimens as large as, much less larger than, the northern forms from Algonquin Park. The host species, age of the host, and degree of infestation are suggested factors which may account for a difference in size of these parasites.

CLEIDODISCUS sp.

Host and Locality.—Yellow Perch *Perca flavescens,* Opeongo Lake in Algonquin Park, Ontario, Canada.

Specimens Studied.—Ten.

These specimens represent a medium-sized dactylogyrid species which possesses anchors and hooks similar to those of *Urocleidus adspectus* Mueller, 1936, but which differs radically from *U. adspectus* in the nature of the copulatory complex. The cirrus and accessory piece are articulated proximally but because of the presence of picric acid in the specimens, the details of these and other critical structures could not be observed well enough for a valid description. A description of this species is contemplated as soon as favorable material is obtained.

Dactylogyrus banghami n. sp.

Pl. 2, Figs. 31-42

Host and Locality.—Common Shiner *Notropis cornutus,* Proulx Lake in Algonquin Park, Ontario, Canada.

Specimens Studied.—Three.

Type Specimens.—Cotypes, Univ. of Notre Dame, Notre Dame, Indiana.

Description.—Length 0.294 mm. (0.270-0.350 mm.), greatest body width 0.078 mm. (0.060-0.082 mm.). Head organs distinct, cephalic lobes four in number and very conspicuous. Eye spots four, often of equal size; members of the posterior pair usually closer together than those of the anterior pair. In some cases one member and in other cases both members of the posterior eye spots are increased in size. Pharynx subspherical in dorsal outline and 0.025 mm. (0.022-0.029 mm.) in transverse diameter. Peduncle short and stout; haptor irregularly ovate in dorsal outline and subquadrate in end view, haptor width 0.049 mm. (0.047-0.052 mm.), length 0.043 mm. (0.039-0.047 mm.). Dorsal bar length 0.020 mm. (0.019-0.021 mm), bent slightly in the middle, and usually with an irregular margin (Pl. 2, Figs. 38, 39). Vestigial ventral bar crescentic in shape (Pl. 2, Fig. 37), 0.014 mm. long, and apparently wanting in some cases. Anchor bases bifurcate, shafts and points solid (Pl. 2, Figs. 31, 32); terminal part of anchor point recurved. Anchor length 0.020 mm. (0.016-0.022 mm.), greatest width of base 0.011 mm. Hooks fourteen in number and arranged as described for the North American freshwater Tetraonchinae (Mizelle 1938a) except that members of pair number six are more ventral than dorsal. Each hook consists of a broadly or narrowly ovate base, a solid shaft approximately twice as long as the base, a sickle-shaped termination, and an opposable piece which is perhaps best developed in hooks of pair number one (Pl. 2, Figs. 40-42). Length of hooks 0.012-0.018 mm. Copulatory complex composed of a cirrus with a basal projection, and a bifurcate accessory piece which articulates with the cirrus near the origin of the basal projection (Pl. 2, Figs. 33-36). The cirrus is subject to slight variation, is pointed, and obliquely truncate terminally (Pl. 2, Figs. 34, 36). Cirrus length 0.036 mm. (0.034-0.038 mm.), accessory piece length 0.024 mm. (0.022-0.027 mm.). Seminal vesicle bulb shaped, comparatively large, and apparently filled with spermatozoa. Only one prostate observed with certainty. Vagina present near midlength of the body proper on the right lower margin. Seminal receptacle and gonads not clearly observed because of heavy development of the vitellaria which extend from the region of the copulatory complex to the peduncle.

The copulatory complexes in the specimens used in this description vary somewhat as shown in Plate 2, Figs. 33-36. This variation, however, is not considered of sufficient magnitude for description of two instead of one species. The closest relatives of *Dactylogyrus banghami* with reference to the cirrus are *D. pollex* n. sp. and *D. bychowskyi* Mizelle, 1937, since these are the only other North American species of this genus which possess a well-defined digiti-

form projection on the cirrus. The projection on the base of *D. photogenis* Mueller, 1938, apparently is of a different nature than those considered here. The accessory piece is of a common or general type which occurs with slight variation in *D. amphibothrium* Wagener, 1857, *D. intermedius* Wegener, 1909, *D. bulbus* Mueller, 1938, and *D. perlus* Mueller, 1938 (Wegener 1909, Figs. 37 & 18 resp.; Mueller 1938, Pl. 3, Figs. 19, 23 resp.) and other species. However, the combination of the cirrus with its basal projection together with the bifid type of accessory piece and the characteristic haptoral armament make the identity of this species very distinct.

DACTYLOGYRUS BULBUS Mueller, 1938

Pl. 2, Figs. 13-23

Host and Locality.—Common Shiner *Notropis cornutus,* Proulx Lake in Algonquin Park, Ontario, Canada.

Previously Reported Host and Locality.—*Notropis cornutus,* Chautauqua Lake, N. Y.

Specimens Studied.—Four.

Redescription.—Length 0.306 mm. (0.270-0.342 mm.), greatest body width 0.056 mm. (0.047-0.069 mm.) "about 0.38 mm. by 0.2 mm." Cephalic lobes well defined and four in number, head organs poorly developed. Eye spots four, of equal size, and with members of each of the two pairs approximately equally separated from each other (transversely). "Posterior pair of eyes slightly larger and farther apart than anterior." Pharynx subcircular to ovate in dorsal view and 0.019 mm. (0.016-0.023 mm.) in transverse diameter about "0.026 mm." Peduncle broad and of moderate length. Haptor roughly hexagonal to irregularly ovate in outline and 0.034 mm. long by 0.054 mm. wide. Anterior border of dorsal bar with a posteriorly directed curve, posterior border comparatively straight except for the presence of a notch near each of the rounded ends; dorsal bar length 0.018 mm. "about 0.022 mm. long." Vestigial ventral bar crescentic in shape and 0.020 mm. long. Each dorsal anchor with 1) a base deeply cleft to form prominent superficial (larger) and deep roots, and 2) solid shafts and points which unite somewhat acutely (Pl. 2, Fig. 13). Anchor length about 0.036 mm., greatest width of base 0.013 mm. "Anchors slender, about 0.035 mm. long." Anchor wings not observed. Hooks normal in number (14) and arrangement. Each consists of an elliptical base about as long or longer than its respective (solid) shaft, a sickle-shaped termination, and a small opposable piece. Hook lengths 0.020-0.025 mm. (Pl. 2, Figs. 14-17). Gonads situated in the posterior body half; testis elongate, fusiform, and with the anterior end overlapping the elliptically ovate ovary which contains several large-nucleated eggs. Vagina, "present on the right ventral margin, but not conspicuous" seminal receptacle, and prostates not observed. Seminal vesicle relatively large and apparently broadly attached to the cirrus base. Copulatory complex composed of a simply curved cirrus 0.031 mm. long (0.020-0.040 mm.) with an inflated termination, and a blade-like

accessory piece with a process near its midlength (Pl. 2, Figs. 18-23). This process in the present specimens is developed "laterally" instead of "dorsally" as originally figured (Mueller 1938, Pl. 3, Fig. 23). A second process suggestive of an extra accessory piece is present below the accessory piece and is attached to the cirrus base (Pl. 2, Fig. 18). Frequently the accessory piece is oriented so that this process is not obvious and this apparently accounts for its absence from the original description. Accessory piece length 0.028 mm. (0.026-0.029 mm.). The cirrus in the present specimens presents a much larger base than that figured in the original description. Vitellaria well developed and extend from the posterior border of the pharynx to or into the peduncle.

Dactylogyrus bullosus n. sp.

Pl. 2, Figs. 24-30

Host and Locality.—Common Shiner *Notropis cornutus,* Proulx Lake in Algonquin Park, Ontario, Canada.

Specimens Studied.—One.

Type Specimen.—Type, Univ. of Notre Dame, Notre Dame, Indiana.

Description.—Length 0.360 mm., greatest body depth 0.095 mm. Members of the posterior pair of eye spots scarcely larger and closer together than those of the anterior pair. Number of cephalic lobes and relative development of the head organs uncertain because of unfavorable orientation of the specimen. Pharynx ovate (vertically elongate) in side view and 0.031 mm. by 0.027 mm. Haptor short and broad, ovate (transversely elongate) in end view, and 0.065 mm. in greatest dimension. Dorsal bar bent posteriorly in the midportion and with rounded ends, length 0.038 mm. Ventral bar not observed. Each dorsal anchor has 1) a bifurcate base separating the long superficial and the short deep root, 2) a solid shaft, and 3) a solid point. Each anchor shaft consists of two straight portions which unite at an angle; the distal portion unites at an angle with the anchor point. Anchor length 0.019 mm., greatest width of base 0.016 mm. Anchor wings moderately developed. Hooks fourteen in number, subequal in length, and with members of pair number five located immediately posterior to where the ventral bar should be. Each hook is provided with a well-developed base, a tapered somewhat enlarged shaft, a well-developed sickle-shaped termination, and a small blunt opposable piece (Pl. 2, Figs. 28-30). Some of the hooks have large ovately outlined bases whereas others possess almost circular-outlined ones. Hook lengths 0.013-0.018 mm. Gonads, seminal receptacle, and prostates not observed. Vagina dextral, chitinized, and situated marginally near the body midlength; seminal vesicle very large. Copulatory complex composed of a sharp-pointed cirrus, and a blade-like accessory piece (Pl. 2, Figs. 26, 27). The cirrus base and about one-half of the shaft on the "dorsal" side is covered with a fleshy material. Cirrus length 0.050 mm. The accessory piece is articulated to the cirrus at the junction of the base and shaft of the latter where an apparent ovate perforation is present. A dorsal process which arises about midway the accessory piece is turned or twisted almost 180 degrees (not shown twisted in Pl. 2, Fig. 27). Accessory piece

length 0.023 mm. The vitellaria in the present specimen are weakly developed and extend from the level of the copulatory complex to the peduncle.

Dactylogyrus bullosus is structurally very closely allied to *D. microphallus* Mueller, 1938, in regard to the general shape of the anchor bases. It differs from this species, however, in the presence of 1) a knobbed accessory piece instead of a bifurcate one, 2) a cirrus with a long instead of a short base, 3) hooks with ovate and subcircular outlined bases instead of strictly elliptically outlined ones, and 4) anchor shafts and points comprised of straight sections united at an angle with each other instead of evenly curved ones (Mueller 1938, Pl. 4, Fig. 11).

DACTYLOGYRUS CORNUTUS Mueller, 1938

Pl. 2, Figs. 50-53

Host and Locality.—Common Shiner *Notropis cornutus,* Proulx Lake in Algonquin Park, Ontario, Canada.

Previously Reported Host and Locality.—*Notropis cornutus,* Chautauqua Lake, N. Y.

Specimens Studied.—One.

Redescription.—Length 0.288 mm., greatest body depth 0.043 mm. "about 0.35 mm. long by 0.08 mm. wide." The single available specimen was turned so as to obscure the number and relative development of the cephalic lobes, relative development of the head organs, and outline of the haptor and the dorsal and vestigial ventral bar in flat view. Peduncle of moderate dimensions. Members of pairs of eye spots of approximately equal size and separation from each other (transversely). Pharynx ovate in outline (side view), greatest diameter (vertical) 0.021 mm., lesser diameter 0.014 mm. "0.026 mm. in diameter." Each dorsal anchor base is cleft and possesses relatively long superficial, and short deep roots (Pl. 2, Fig. 53). The solid anchor shaft is bent at one point, toward the point with which it unites acutely. Anchor length 0.034 mm., greatest width of base, 0.016 mm. "about 0.039 mm. long." Anchor wings not observed. Hooks fourteen in number, subequal in length (0.016-0.020 mm.); each composed of a relatively large ovate or elliptical base about the length of the slender shaft (Pl. 2, Fig. 52 and Mueller 1938, Pl. 3, Fig. 8), a sickle-shaped termination, and a small opposable piece. Vagina "on right," seminal receptacle, seminal vesicle, prostates, and testis not observed. Ovary situated in the anterior part of the posterior body half, vermiform in outline, curving from ventral to dorsal body regions, and filled with many well-defined nucleated eggs which increase in size in a posterior-anterior direction. Copulatory complex composed of a cirrus of a broad inverted U-shape, and a short curved solid accessory piece attached to the cirrus base (Pl. 2, Figs. 50, 51). The cirrus is 0.036 mm. long and has a slightly enlarged proximal portion instead of one about the same size of the rest of the shaft (Mueller 1938, Pl. 3, Fig. 7). The accessory piece (about 0.013 mm. long) is also different and oppositely directed from that figured in the original description and probably represents a variation or *vice versa.* Vitellaria well developed and extend from the posterior border of the pharynx into the peduncle.

DACTYLOGYRUS PERLUS Mueller, 1938

Pl. 2, Figs. 1-12

Host and Locality.—Common Shiner *Notropis cornutus,* Proulx Lake in Algonquin Park, Ontario, Canada.

Previously Reported Host and Locality.—*Notropis cornutus,* Chautauqua Lake, N. Y.

Specimens Studied.—One.

Redescription.—The single specimen available in this work presents several features which should be appended to the original description. Length 0.273 mm., greatest body width 0.069 mm. "about 0.035 by 0.09 mm." Head organs prominent, cephalic lobes well defined and four in number (Pl. 2, Figs. 2-5). Eye spots four, approximately the same size and with members of the posterior pair closer together than those of the anterior pair "equally separated." Pharynx subcircular in outline (dorsal view) and 0.022 mm. in transverse diameter "0.023 mm. in diameter." Peduncle short and stout. Haptor subquadrate in outline and with a median notch on the posterior border; width 0.052 mm. length 0.040 mm. Dorsal bar slightly bent posteriorly in the middle and with enlarged ends (Pl. 2, Fig. 9), length 0.024 mm. Vestigial ventral bar not observed. Each anchor (dorsal) composed of 1) a deeply bifurcate base with the superficial root noticeably longer than the deep root, 2) a solid shaft and 3) a solid point (Pl. 2, Fig. 12). Anchor length 0.025 mm. "0.028 mm,." width not available. Anchor wings moderately developed. Hooks (14) arranged as in the North American Tetraonchinae (Mizelle 1938a) and subequal in length (0.011-0.015 mm.) "0.018 mm." Each of the hooks is composed of a moderate-sized base, a solid shaft, a sickle-shaped termination, and a small opposable piece. The hook bases (Pl. 2, Figs. 10, 11) were observed to be relatively much shorter than those figured in the original description (Mueller 1938, Pl. 3, Fig. 22). Copulatory complex composed of a strongly curved cirrus and a blade-like accessory piece with a prominent projection near its midlength (Pl. 2, Figs. 7, 8); accessory piece length 0.021 mm. Cirrus 0.031 mm. long, tapered terminally to a comparatively small diameter and possesses a more highly chitinized base than originally figured (Mueller 1938, Pl. 3, Fig. 19). Seminal vesicle relatively large and apparently filled with spermatozoa. Prostates two in number; one filled with a yellow hyaline material and the other containing a coarsely granular yellow substance. Testis not observed. Vagina situated about midway the body on the right margin toward the ventral surface. Ovary axial, situated immediately posterior to the level of the vagina, vermiform in nature, and containing about six eggs which become progressively larger anteriorly. Seminal receptacle not observed. Vitellaria well developed and extending from the region of the copulatory complex into the peduncle.

Dactylogyrus pollex n. sp.

Pl. 2, Figs. 43-49

Host and Locality.—Common Shiner *Notropis cornutus,* Proulx Lake in Algonquin Park, Ontario, Canada.

Specimens Studied.—One.

Type Specimen.—Type, Univ. of Notre Dame, Notre Dame, Indiana.

Description.—Length 0.306 mm., greatest body depth 0.077 mm. The single specimen available here was orientated so as to obscure the number of cephalic lobes present, and the relative development of the head organs. Members of the posterior pair of eye spots closer together and noticeably larger than those of the anterior pair. Pharynx pyriform (vertically elongate) in side view and 0.034 mm. by 0.025 mm. Peduncle short and stout; haptor subquadrate in end view and 0.053 mm. in greatest dimension. Dorsal bar bent gently posteriorly in the middle and with obliquely truncate ends (Pl. 2, Fig. 48), bar length 0.018 mm. Vestigial ventral bar not observed. Each anchor (dorsal) with a broadly bifurcate base, a solid shaft, and a solid point the tip of which is recurved. Configuration of anchor shafts and points similar to that of *D. bullosus* n. sp. The superficial root of each anchor base is longer than the deep root (Pl. 2, Fig. 49). Anchor length 0.020 mm., greatest width of base 0.014 mm. Anchor wings double and inconspicuous. Hooks fourteen in number, subequal in length, and each composed of an irregularly ovate to elliptically outlined base, a solid shaft which is longer than the respective base, a sickle-shaped termination, and a small opposable piece; hook lengths 0.014-0.019 mm. In some instances the hooks appear to have a base of a double nature (Pl. 2, Figs. 46, 47). The copulatory complex consists of a cirrus with a thumb-like structure near its midlength, and a solid blade-like accessory piece which possesses an anteriorly projecting structure near its middle (Pl. 2, Figs. 44, 45). The cirrus base is approximately the same length as the cirrus shaft and gives rise to the thumb-like projection at its distal portion. The cirrus shaft possesses a small cirral thread near its termination. Cirrus length 0.041 mm., accessory piece length 0.022 mm. Seminal vesicle well developed. Vagina dextral, highly chitinized, and situated near the body midlength toward the ventral surface. Gonads and seminal receptacle obscured by heavy development of the vitellaria which extend from the level of the anterior part of the copulatory complex to the peduncle. Two prostates similar to those described herein for *D. perlus* Mueller, 1938, present.

This species possesses anchors which remotely resemble those of *D. microphallus* Mueller, 1938, but the accessory piece is somewhat similar to that of *D. perlus* Mueller, 1938, or perhaps *D. photogenis* Mueller, 1938. The cirrus of *D. pollex* differs from that of the above-named species by the presence of a thumb-like structure, a thread around the distal portion of the shaft, and in shape. A digitiform projection is present also on the cirrus of *D. banghami* n. sp. and *D. bychowskyi* Mizelle, 1937, but otherwise, similarities of these species to *D. pollex* are remote.

UROCLEIDUS ADSPECTUS Mueller, 1936

Pl. 2, Figs. 54-65

Host and Localities.—Yellow Perch *Perca flavescens*, Long, Opeongo, and Proulx Lakes in Algonquin Park, Ontario, Canada.

Previously Reported Host and Locality.—*Perca flavescens*, Cross Lake, N. Y.

Specimens Studied.—Sixteen.

Redescription.—The specimens available in this work were in poor condition for detailed study since they were contracted to a great extent and the vitellaria were so highly developed that observation of certain internal structures was practically impossible. A very favorable specimen obtained from a local market was used as an adjunct in the following description. Medium-sized dactylogyrids with a rugose cuticula in contracted specimens, length 0.357 mm. (0.214-0.614 mm.); greatest body width 0.136 mm. (0.087-0.186 mm.), "Total length: 0.28-0.35 mm." Cephalic lobes of moderate size, head organs poorly developed. Pharynx circular to ovate in outline (dorsal view) and with a transverse diameter of 0.044 mm. (0.038-0.052 mm.) "about 0.05 mm." Peduncle short and stout; haptor roughly pentagonal to quadrate in outline, haptoral bars variable in shape. Dorsal bar usually with enlarged obliquely truncate or rounded ends and often with a raised portion on the anterior border, length 0.041 mm. (0.036-0.044 mm.) (Pl. 2, Figs. 55-58). Ventral bar of the same general shape except that the raised portion on the anterior margin is wanting, the margins are usually entire, and a blunt projection is present on the posterior margin, (Pl. 2, Figs. 61-63), length 0.043 mm. (0.038-0.046 mm.), "Supporting bars about 0.040 mm. long." Anchors relatively large, similar in shape, often dissimilar in size, and with hollow shafts and points (Pl. 2, Figs. 54, 59, 60); anchor wings of a double nature. The "cavity" in each anchor shaft is peculiar in that it arises near the convex border rather than in the middle of the structure. Each anchor base is bifurcate to form a long superficial root and a broad short deep root with a rounded margin. Ventral anchor length 0.048 mm. (0.041-0.055 mm.), greatest width of base 0.034 mm. (0.025-0.036 mm.); dorsal anchor length 0.046 mm. (0.032-0.052 mm.), greatest width of base 0.032 mm. (0.025-0.036 mm.); "Length of anchors: 0.04 mm. for the dorsal, 0.05 for the ventral." The hooks are normal in number and position (Mizelle 1938a) with members of pair number five situated between the ventral anchor shafts. Each hook consists of an ovate or elliptical base, a slender solid shaft much longer than the base, a sickle-shaped termination, and an opposable piece. Hook lengths 0.015-0.022 mm. No genital structures were observed except the copulatory complex which consists of a simply curved hollow cirrus 0.030 mm. (0.029-0.033 mm.) long, and an accessory piece of a complex type (Pl. 2, Figs. 64, 65). The latter structure is 0.022 mm. (0.017-0.026 mm.) long and composed of two rami which unite distally and terminate in a pointed structure. Occasionally one of the rami was faintly observed to unite proximally with the cirrus base. If this articulation is present this species belongs in the genus *Cleidodiscus* Mueller, 1934, instead of *Urocleidus* Mueller, 1934. Its correct generic status awaits study of more favorable or possibly type material. The copulatory complex described herein varies greatly from the figure accompanying the original description (Mueller 1936 Pl. 14, Fig. 28) and may represent a radical variation, a different species (doubtful), or it may be that the original description is in error in this particular respect. Vitellaria at times heavily developed, extending from the posterior border of the pharynx to the peduncle, and often containing melanistic granules of varying sizes. *U. adspectus* is the only monogenetic trematode previously recorded from the gills of the yellow perch.

UROCLEIDUS DISPAR (Mueller, 1936) Mizelle and Hughes, 1938

Synonyms.—*Onchocleidus dispar* Mueller, 1936, and *Haplocleidus dispar* (Mueller, 1936) Mueller, 1937.

Host and Localities.—Pumpkinseed Sunfish *Lepomis gibbosus,* Long, Opeongo, and Proulx Lakes in Algonquin Park, Ontario, Canada.

Previously Reported Hosts and Localities.—*Lepomis gibbosus,* Constantia, N. Y. (Mueller 1936). Bluegill Sunfish *Lepomis macrochirus,* Local Streams and Ponds near Stillwater, Okla. (Seamster 1938) and Various Localities in Illinois (Mizelle 1938a). Orange-Spoted Sunfish *Lepomis humilis,* Local Ponds and Streams near Stillwater, Okla. (Seamster 1938).

Specimens Studied.—Twelve.

The specimens available here, like those of *Cleidodiscus banghami* were in such poor condition that a valid comparative or redescription was impossible. The identity of them, however, is unmistakable. The short sculptured cirrus, the characteristic accessory piece, and the absence of a vagina, readily distinguish it from its closest relative *Urocleidus parvicirrus* Mizelle and Jaskoski, 1942. The specimens agree with original description in all important details with the exception that in some instances the distal prongs of the accessory piece do not unite to form a ring as originally figured.

UROCLEIDUS FEROX Mueller, 1934

Synonyms.—*Onchocleidus ferox* (Mueller, 1936) Mueller, 1936, and *Onchocleidus mucronatus* Mizelle, 1936.

Host and Localities.—Pumpkinseed Sunfish *Lepimos gibbosus,* Brewer, Costello, Long, Opeongo, and Proulx Lakes in Algonquin Park, Ontario, Canada.

Previously Reported Hosts and Localities.—Pumpkinseed Sunfish *Lepomis gibbosus* Oneida Lake, N. Y. (Mueller 1934), Constantia, N. Y. (Mueller 1936), and Lake Senachwine, Henry, Ill. (Mizelle 1936). Bluegill Sunfish *Lepomis macrochirus,* Lake Decatur, Decatur, Ill., State Natural History Survey Pond, Urbana, Ill., Lake Senachwine, Henry, Ill., (Mizelle 1936), Boomer Creek, Stillwater, Okla. (Mizelle 1938a), Local Ponds and Streams near Stillwater, Okla. (Seamster 1938), Baton Rouge and New Roads, La. (Summers and Bennett 1938), Reelfoot Lake, Ridgely, Tenn., and Lake Okeechobee, Moore Haven, Fla. (Mizelle and Brennan 1942). Orange-Spotted Sunfish *Lepomis humilis,* Lake Senachwine, Henry, Ill., Salt Fork of the Big Vermillion River, Homer, Ill. (Mizelle 1936), and Local Ponds and Streams near Stillwater, Okla. (Seamster 1938). Hybrids (Orange-Spotted X Pumpkinseed and Bluegill X Pumpkinseed Sunfishes), Lake Senachwine, Henry, Ill. (Mizelle 1936).

Specimens Studied.—Sixteen.

The identity of this species, which is the dominant form on the above-listed hosts, has been in confusion since the original description by Mueller in 1934. Mizelle working in Illinois, could not recognize it as being *U. ferox* principally because of the stated absence of an accessory piece in the copulatory

complex, and described it as a new species (*Onchocleidus mucronatus*). In the Algonquin Park material a few specimens were found which apparently did not possess an accessory piece. On closer examination, however, the apparent absence of this structure was thought to be because of obscuring yellow color imparted by a picric acid fixer, or the orientation of the specimens so that the accessory piece was presented in flat view and was almost invisible. Type hosts from the type locality were kindly supplied by the State of New York Conservation Department and formalin-fixed specimens were examined to see whether or not an accessory piece was present in topotypes. Points regarding the Algonquin Park specimens were readily confirmed and now it can be definitely stated that *U. mucronatus* (Mizelle, 1936) is a synonym of *U. ferox* Mueller, 1934. The confusion produced in this instance illustrates the fact that many synonyms could be avoided provided original authors would use sufficient specimens (especially when they are readily available) in the description of new species. The present authors feel that descriptions based on a number of cotypes are much more informative than those involving a single type specimen. Mizelle's description of this species as *O. mucronatus* published in 1938(a) was based on twenty specimens and probably should be consulted rather than the original because of mistakes and omissions in the latter. To mention some of these the authors find that the original author 1) overlooked the presence of the accessory piece, 2) overlooked one prostate, 3) figured the cirrus with an inflation at the base (Mueller 1934, Pl. 47, Fig. 7), 4) figured each of the hooks of pair number five (seven of Mueller) as having an inflated shaft and without a base (Mueller 1936, Pl. 13, Fig. 12 and Mizelle 1938a, Pl. 2, Fig. 9), 5) overlooked the presence of a small cirral thread which is seen in some cases with difficulty, and 6) overlooked the spines on the haptoral bars, which are best seen in side view (Mueller 1936, Pl. 13, Fig. 12 and Mizelle 1938a, Pl. 3, Figs. 26, 27).

Several variations in specimens from various localities, considered worthy of mention are 1) members of the posterior eye spots in Algonquin Park specimens are often abnormally large and contiguous or confluent, 2) the vagina or vaginal tube is either straight, zigzag, or undulate in outline (Mueller 1936, Pl. 15, Figs. 61, 62 and Mizelle 1938a, Pl. 3, Fig. 29), 3) the seminal receptacle is generally ovoid and seldom heart-shaped in outline, 4) the cirrus may be straight or slightly undulate, and 5) the cirral thread may be so small as to escape observation or it may be well developed. The Algonquin Park material conforms with the original description in all important points.

Urocleidus procax n. sp.

Pl. 1, Figs. 62-68

Host and Localities.—Pumpkinseed Sunfish *Lepomis gibbosus,* Long and Opeongo Lakes in Algonquin Park, Ontario, Canada.

Specimens Studied.—Seventeen.

Type Specimens.—Cotypes, Univ. of Notre Dame, Notre Dame, Indiana.

Description.—Length 0.359 mm. (0.291-0.455 mm.), greatest body width

0.052 mm. (0.030-0.077 mm.). Cephalic lobes small, head organs (usually) poorly defined. Eye spots four, members of the posterior pair much larger and closer together (infrequently contiguous) than members of the anterior pair. Pharynx subcircular in outline (dorsal view) and 0.017 mm. (0.014-0.023 mm.) in transverse diameter. Peduncle moderate in size; haptor pentagonal or hexagonal in outline, width 0.078 mm. (0.073-0.086 mm.), length 0.067 mm. (0.060-0.073 mm.). Haptoral armament of much the same morphology as that of *Urocleidus ferox* Mueller 1934, (Mizelle 1938a Pl. 2, Fig. 9). Ventral bar frequently with a projection on the anterior and posterior surfaces as shown in Pl. 1, Fig. 68. Dorsal bar usually bent posteriorly in the middle and often with a tubercle on the anterior surface near each end similar to that of *U. interruptus* (Mizelle, 1938a Pl. 4, Fig. 107). Ventral bar length 0.024 mm. (0.022-0.026 mm.), dorsal bar length 0.025 mm. (0.016-0.029 mm.). Two pairs of anchors of approximately the same size and with long solid shafts which unite somewhat acutely with the solid points. Anchor bases with superficial roots much larger than the deep roots. Ventral anchor length 0.051 mm. (0.045-0.056 mm.), greatest width of base 0.015 mm. (0.011-0.018 mm.); dorsal anchor length 0.050 mm. (0.046-0.056 mm.), greatest width of base 0.012 mm. (0.010-0.014 mm.). Anchor wings well developed and frequently double. Hooks fourteen in number and normal in arrangement (Mizelle 1938a) with members of pair number five situated between the shafts of the ventral anchors. Hooks of pair number five relatively small, 0.010-0.012 mm. long, and usually with a small oval base, a slender shaft, a sickle-shaped termination, and an opposable piece. Infrequently the base is absent and the shaft appears enlarged. The rest of the hooks are of similar morphology except that the bases may be absent, that is developed so as to obliterate the shaft which is present in some members of different hook pairs and when so, is always shorter, than the accompanying long elliptical base. Hooks (exclusive of pair number five) subequal in length (in a given specimen) and measuring 0.032 mm. (0.026-0.036 mm.). Gonads ovate to elliptical in outline, tandem in arrangement, and with the ovary situated anterior to the testis. Seminal vesicle bulbshaped, seminal receptacle not observed. Vagina not observed with certainty but apparently very lightly chitinized and located on the right margin near the midlength of the body. The copulatory complex consists of 1) a relatively short cirrus which possesses a thread around its shaft and 2) an accessory piece of variable morphology and nonarticulate with the cirrus base (Pl. 1, Figs. 62-67). Cirrus length 0.028 mm. (0.027-0.031 mm.), accessory piece length 0.018 mm. (0.016-0.022 mm.). Vitellaria well developed and extend to or into the peduncle.

The morphology of the haptor of *U. procax* in general resembles that of *Urocleidus ferox* Mueller, 1934 (Mizelle 1938a, Pl. 2, Fig. 9). The copulatory complex is intermediate between that of *U. dispar* (Mueller, 1936) and *U. ferox* (see Mueller 1936, Pl. 14, Fig. 24, and Mizelle 1938a, Pl. 3, Figs. 22, 23). Except for the absence of a cirral thread and minor details the cirrus though much shorter, resembles that of *Urocleidus perdix* (Mueller 1937, Fig. 9B) described from the bluegill (*Lepomis macrochirus*) from Florida.

Summary

A collection of branchial material obtained by Dr. R. V. Bangham of Wooster College, Wooster, Ohio, from fishes in Algonquin Park, Ontario, Canada, was examined. All the hosts represented were infected except the finescale dace *Pfrille neogaea* from Costello Creek. Nine previously described, and ten new species were recovered. These are, *Actinocleidus gibbosus*, n. sp. from *Lepomis gibbosus* from Opeongo Lake; *A. incus* n. sp. from *Lepomis gibbosus* from Opeongo Lake; *A. oculatus* (Mueller, 1934) from *Lepomis gibbosus* from Long and Opeongo Lakes; *A. recurvatus* n. sp. from *Lepomis gibbosus* from Costello, Long, Opeongo, and Proulx Lakes; *A. scapularis* n. sp. from *Lepomis gibbosus* from Opeongo Lake; *A. sigmoideus* n. sp. from *Lepomis* gibbosus from Costello, Long, Opeongo, and Proulx Lakes; *Cleidodiscus banghami* (Mueller, 1936) from *Micropterus dolomieu* from Opeongo Lake; *C. pricei* Mueller, 1936, from *Ameiurus melas* from Opeongo Lake, and *A. nebulosus* from Dixon, Proulx and Smoke Lakes; *Cleidodiscus* sp. from *Perca flavescens* from Opeongo Lake; *Urocleidus adspectus* Mueller, 1936, from *Perca flavescens* from Long, Opeongo, and Proulx Lakes; *U. dispar* (Mueller, 1936) from *Lepomis gibbosus* from Long, Opeongo, and Proulx Lakes; *U. ferox* Mueller, 1934 from *Lepomis gibbosus* from Brewer, Costello, Long, Opeongo, and Proulx Lakes; *U procax* n. sp. from *Lepomis gibbosus* from Long and Opeongo Lakes; and *Dactylogyrus banghami* n. sp., *D. bulbus* Mueller, 1938, *D. bullosus* n. sp., *D. cornutus* Mueller, 1938, *D. perlus* Mueller 1938, and *D. pollex* n. sp., all from *Notropis cornutus* from Proulx Lake.

This study represents the first work on Gyrodactyloidea from the abovenamed localities.

PLATE 1

PLATE 1.—All figures were made at the same magnification with the aid of a camera lucida.

Figs. 1-8. *Actinocleidus scapularis* n. sp.—1, Anterior anchor. 2, Anterior bar. 3, Posterior anchor. 4, Posterior bar. 5, Accessory piece. 6, Cirrus. 7, 8, Hooks.

Figs. 9-17. *Actinocleidus oculatus* (Mueller, 1934) Mueller, 1937.—9, Anterior anchor. 10, Anterior bar. 11, Posterior anchor. 12, Posterioor bar. 13, Hook. 14, 16, Accessory pieces. 15, 17, Cirri.

Figs. 18-33. *Actinocleidus sigmoideus* n. sp.—18, Anterior anchor. 19, Anterior bar. 20, Posterior anchor. 21, Posterior bar. 22, 23, Hooks. 24-28, Accessory pieces. 29-33, Cirri.

Figs. 34-42. *Actinocleidus gibbosus* n. sp.—34, 35, Posterior anchors. 36, Posterior bar. 37, Anterior bar. 38, 39, Anterior anchors. 40, Accessory piece. 41, Cirrus. 42, Hook.

Figs 43-49. *Actinocleidus incus* n. sp.—43, Anterior anchor. 44, Anterior bar. 45, Posterior anchor. 46, Posterior bar. 47, Accessory piece. 48, Cirrus. 49, Hook.

Figs. 50-61. *Actinocleidus recurvatus* n. sp.—50, 51, Anterior anchors. 52, Posterior anchor. 53-55, Hooks. 56-57, Vaginal tubes. 58, Anterior bar. 59, Posterior bar. 60, Accessory piece. 61, Cirrus.

Figs. 62-68. *Urocleidus procax* n. sp.—62, 64, 66, Accessory pieces. 63, 65, 67 Cirri. 68, Ventral bar.

PLATE 1

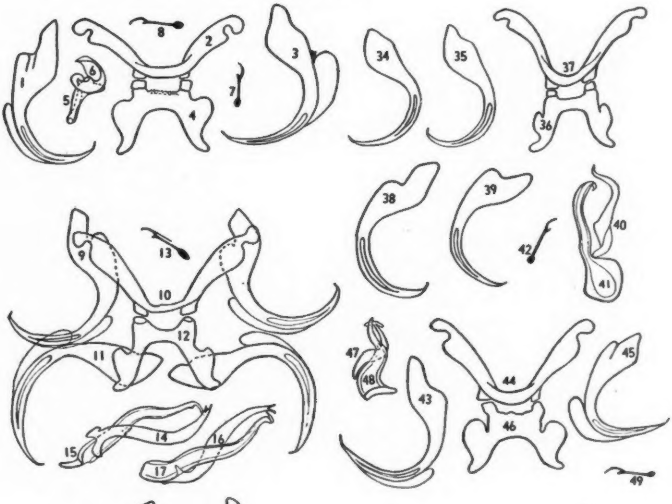
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PLATE 2

PLATE 2.—All figures were made at the same magnification with the aid of a camera lucida.

Figs. 1-12. *Dactylogyrus perlus* Mueller, 1938.—1, Eye spots. 2-5, Cephalic lobes. 6, Pharynx. 7, Accessory piece. 8, Cirrus. 9, Dorsal bar. 10-11, Hooks. 12, Anchor.

Figs. 13-23. *Dactylogyrus bulbus* Mueller, 1938.—13, Anchor. 14-17, Hooks. 18-20, Cirri. 21-23, Accessory pieces.

Figs. 24-30. *Dactylogyrus bullosus* n. sp.—24, Anchor. 25, Seminal vesicle. 26, Cirrus. 27, Accessory piece. 28-30, Hooks.

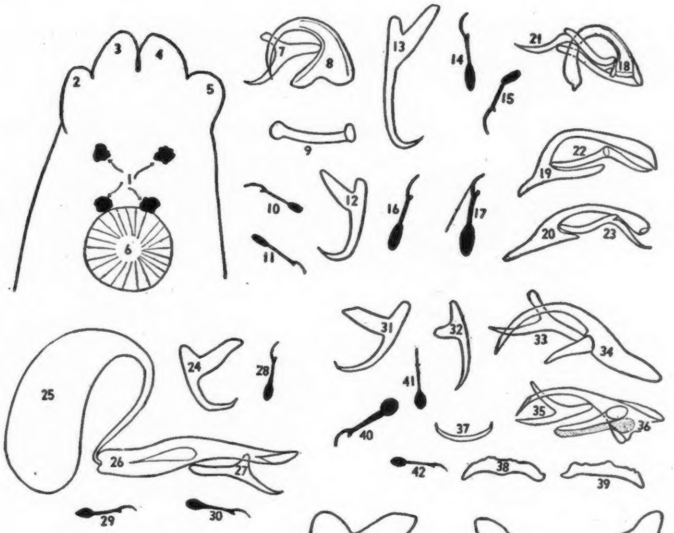
Figs. 31-42. *Dactylogyrus banghami* n. sp.—31, 32, Anchors. 33, 35, Accessory pieces. 34, 36, Cirri. 37, Ventral bar. 38, 39, Dorsal bars. 40-42, Hooks.

Figs. 43-49. *Dactylogyrus pollex* n. sp.—43, Seminal vesicle. 44, Cirrus. 45, Accessory piece. 46, 47, Hooks. 48, Dorsal bar. 49, Anchor.

Figs. 50-53. *Dactylogyrus cornutus* Mueller, 1938.—50, Accessory piece. 51, Cirrus. 52, Hook. 53, Anchor.

Figs. 54-65. *Urocleidus adspectus* Mueller, 1936—54, Dorsal anchor. 55-58, Dorsal bars. 59, 60, Ventral anchors. 61-63, Ventral bars. 64, Accessory piece. 65, Cirrus.

PLATE 2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Parasites of Beavers, With a Note on Paramphistomum castori Kofoid and Park, 1937 a Synonym of Stichorchis subtriquetrus[1]

Arnold B. Erickson

The species of internal parasites that infect the American beaver (*Castor canadensis*) unlike those that infect the muskrat (*Ondatra zibethica*) are few in number. A total of six well authenticated species of helminths has been recorded. They are the trematodes *Stichorchis subtriquetrus, Stephanoproraoides lawi,* and *Renifer ellipticus,* and the nematodes *Travassosius americanus, Castorstrongylus castoris,* and *Capillaria hepatica.* Four other species have been listed, but they are of doubtful position and occurrence. They are the trematode *Paramphistomum castori* and the nematodes *Filaria* sp., *Gongylonema* sp., and *Oxyuris* sp. It is probable, as will be shown later, that *P. castori* is a synonym of *Stichorchis subtriquetrus.* Two helminths which have been reported for the Norwegian beaver (*Castor fiber*), *Travassosius rufus* and *Fasciola hepatica,* may be looked for in the American beaver.

For an animal that spends so much of its time in the water where infection by helminths, especially trematodes, occurs readily, six species of helminths make a surprisingly short list. The small number recorded for the beaver probably results from the fact that it subsists largely on the bark and twigs of aspen and avoids contamination of its food. The paucity of parasitological examinations may also be a reason why so few helminths have been reported.

Morgan (1868) in his book "The American Beaver and His Works" was probably the first to record and describe parasites of the American beaver. In a footnote on page 73 he writes, "In the stomach of the beaver I have found a very fine filamentous worm, 40″ in length, species unknown. Large numbers of a long, slender white worm 3″ to 5″ in length were found in the peritoneal cavity (Filaria species not known), also in the colon, and especially in the caecum, sclerostema, males and female, species not known, and the amphistoma subtriquetrum."

Hall (1916), relying wholly on the brief discussion of Morgan, listed under the name *Gongylonema* the filamentous worm found by this author in the stomach of the beaver. Also, he listed the *Filaria* found by Morgan and states that it was probably a *Setaria.* The sclerostomes found in the colon and cecum by Morgan were listed by Hall under the name of *Strongylus* sp. This worm probably was the species described by Chapin in 1925 under the name

1 Paper No. 2027 Scientific Journal Series Minnesota Agricultural Experiment Station, St. Paul. Prepared under joint cooperation by the Division of Entomology and Economic Zoology, University of Minnesota, and the Pittman-Robertson Project 11-R, Minnesota Division of Game and Fish, Department of Conservation.

of *Castorstrongylus castoris*. The *Amphistoma subtriquetrum* mentioned by Morgan is a synonym of *Stichorchis subtriquetrus*.

In the same paper in which he described the strongyle, *C. castoris*, Chapin also described the stomach worm, *Travassosius americanus*. This species is similar to *T. rufus* of the Norwegian beaver described by Khalil in 1922. Price (1934) described the curious Y-shaped trematode *Stephanoproraoides lawi*, three specimens of which were forwarded to him by R. G. Law of Kirkfield, Ontario. In 1934 Chitwood recorded the first and only known case of *Capillaria hepatica* from the liver of a beaver. This animal died in the National Zoological Park, Washington, D. C. Also, in 1934 Canavan found the trematode *Renifer ellipticus* in a beaver that died in the Philadelphia Zoological Garden. This trematode is normally parasitic in the mouths of snakes. Its occurrence in the beaver must be regarded as highly unusual. In addition to reporting *R. ellipticus*, Canavan (1929) in a table of hosts examined indicates that of 17 beavers which died in the Philadelphia Zoological Garden four contained *Oxyuris*. There is no further statement in the text concerning these worms. In 1931 Canavan reported finding *Castorstrongylus castoris* in beavers in the Philadelphia Zoological Garden.

Law and Kennedy (1932) found the fluke *Stichorchis subtriquetrus* in beavers in Ontario. Their record is also given in Swales' (1933) review of Canadian helminthology. No work on the life history of *S. subtriquetrus* had been published until Bennett and Humes (1939) reported on the pre-cercarial development of this species. Adult flukes were obtained by them from *Castor canadensis carolinensis* at Gonzales, Louisiana. Eggs obtained from the flukes began hatching at the end of the third week, and the resulting miracidia were found to penetrate the amphibious snail *Fossaria parva* and there continues their development. Orlov (1941) has shown that cercariae of *S. subtriquetrus* are liberated 35 days after the invasion of the snail host and that encystment of the cercariae occurs after 18 hours.

Kofoid and Park (1937) described the fluke *Paramphistomum castori* from *C. canadensis baileyi*. The host was taken in Elko county, Nevada. Although they placed this fluke in the genus *Paramphistomum* subfamily Paramphistominae, their description and illustrations of it apply much more closely to the genus *Stichorchis*, subfamily Cladorcinae, or according to the more recent classification of Näsmark (1937), Stichorchinae. Their fluke is characterized by the presence of a cirrus pouch, highly branched testes, and vitellaria which extend from the anterior level of the posterior testis to the posterior end of the body. These anatomical features are all characteristic of the subfamily Stichorchinae and not of the Paramphistominae. The authors do not mention or figure pharyngeal sacs, an important character for separating the Paramphistominae from the Stichorchinae. Curiously enough they do not mention the fluke *Stichorchis subtriquetrus* which is commonly reported from beavers in the United States and Canada.

Through the courtesy of Dr. Kofoid and Dr. Kirby, of the Department of Zoology, University of California, I have been permitted to examine three

slides of the amphistome from the beaver. In addition, I have examined a slide which Kofoid and Park deposited in the U. S. National Museum. All of the slides are of whole mount specimens which have been compressed to permit greater clearing.

Two of the specimens have definite pharyngeal sacs, a characteristic feature of the genus *Stichorchis* but one lacking in the genus *Paramphistomum*. The degree to which the pharyngeal sacs are evident depends on fixation, type of stain, and amount of clearing. My own experience is that they are not always readily brought out in whole mount preparations.

The fluke that Kofoid and Park have described as *Paramphistomum castori* compares in all important features with the whole mounts and sections of *Stichorchis subtriquetrus* which I have obtained in abundance from beavers in Minnesota. The fact that *P. castori* has a cirrus pouch, highly branched testes, vitellaria which extend from the testes to the posterior end of the body, and pharyngeal sacs, leads me to suggest that it is identical with *S. subtriquetrus* and should be regarded as a synonym of that species.

Autopsies of 140 beavers have been completed in our laboratory at University Farm since 1937. The majority of the animals were obtained during the 1941 and 1942 trapping seasons through the cooperation of the Pittman-Robertson Project 11-R of the Minnesota Division of Game and Fish. Fifteen animals were obtained in 1937 and 1938 from Mr. Shaler Aldous and Mr. J. Manweiler, and Dr. F. G. Wallace contributed four autopsy records of beavers taken in 1937. Although no new species of parasites were found in this group of animals, data on the distribution and incidence of four species of helminths and on disease conditions were obtained.

The beavers were trapped in 23 of the 87 counties of the state, and all sections of the state were represented. Northern and much of east-central Minnesota are considered optimum beaver range. The southern agricultural portion, however, is poor beaver range, but in a number of areas beavers occur. There is some evidence that animals from this area are apt to be more heavily parasitized and diseased than animals from northern Minnesota.

Four species of helminths have been found in Minnesota beavers: the cecal fluke (*Stichorchis subtriquetrus*), the small intestinal fluke (*Stephanoprorao-ides lawi*), the stomach worm (*Travassosius americanus*), and the intestinal strongyle (*Castorstrongylus castoris*).

The stomach worm and the cecal fluke are widely distributed among beavers throughout their range in Minnesota as evidenced by the fact that some animals from each county, and usually a large percentage, were parasitized by both of these helminths. The stomach worm was found in 124 out of 140 beavers or in 88.57 per cent. The average number of worms per infected animal was 142 and the maximum number was 1,197. Usually they lay next to the mucous lining of the stomach and were most abundant in the cardiac portion, which in the beaver is exceedingly thick and glandular. Even in heavy infestations there was no evidence that the worms were causing injury to the

stomach lining, although they are probably bloodsuckers. That they may injure the host by the production of toxins is not beyond possibility. The life cycle of the stomach worm is not known, but it is probably simple and direct.

The cecal fluke was recovered from 110 out of 140 animals or in 78.57 per cent. The average number of flukes per infected beaver was 29, and the maximum number was 263. Occasionally these flukes are found in the large intestine, but the cecum is their normal habitat. They did not seem to injure the hosts. Orlov (1941), however, states that *Stichorchis subtriquetrus* infections were responsible for considerable mortality of beavers in the Varonezh region of Russia in 1940. The complete life cycle of this fluke is not known, but it is recognized that the pre-cercarial development can take place in the snail *Fossaria parva*. This snail occurs in Minnesota and is widely distributed throughout the United States and Canada. Seventy per cent of the beavers examined harbored concurrent infections of the stomach worm and the cecal fluke.

The strongyle (*C. castoris*) and the intestinal fluke (*S. lawi*) occur locally in Minnesota in beavers. Ten out of 140 or 7.1 per cent of the beavers examined contained the strongyle in the small intestine. The average number of worms per infected host was 16, and the maximum number was 59. Six out of 11 animals that were trapped in Carlton County near the St. Louis river were parasitized as were two each from Grand Marais, Cook county, and Baudette, Lake of the Woods county. The life cycle of this nematode has not been investigated.

The type locality of *S. lawi* is Kirkfleld, Ontario, where R. G. Law obtained three specimens in 1932. Since its discovery there have been no new locality records reported for this species. In Minnesota, however, two specimens were recovered by Dr. O. W. Olsen in 1938 from a beaver collected at Ely, St. Louis county, Minnesota. In 1942 the writer collected four specimens from a beaver trapped at Grand Marais. Only 1.42 per cent of the beavers examined in our laboratory have been parasitized by this fluke. Nothing is known of its life history.

External parasites are rarely found on beavers. The beetle (*Platypsylla castoris*) is probably the commonest of the six forms known to parasitize this host. In the collections of the Division of Entomology and Economic Zoology, University of Minnesota, there are but three records of *P. castoris* from Minnesota beavers. Six specimens were recovered by Dr. Wm. L. Jellison from a beaver trapped in Cook County in April, 1931. Dr. Gustav Swanson collected one specimen on May 13, 1939, from an animal taken in eastern Minnesota. On April 17, 1941, Mr. L. J. McCann removed one specimen from a beaver that was live-trapped near Austin, Minnesota. This animal harbored many of these beetles, but unfortunately only one specimen was obtained.

The beetle (*Leptinillus validus*) has been reported for beavers only a few times. Bailey (1923) examined four adult beavers in Wisconsin and recovered two specimens. Riley (1892) in Appendix C, page 238, of the book "Castor-

ologia" by H. T. Martin records the finding of *L. validus* on beaver skins from Alaska.

Osborn (1896) described the biting louse *Trichodectes castoris* from specimens collected from a beaver by Professor Lawrence Bruner. No locality is given. This seems to be the first and only record of biting lice from the beaver. Stiles (1910) recorded the first and only record of a tick (*Dermacentor albipictus*) from the beaver. Trouessat (1896) reported the mite, *Schizocarpus mingaudi*, from beavers taken in California and in Europe. Finally Cook (1940) reported that three of 40 beavers trapped in Kimble county, Texas, in 1939 were infected by larvae of the screwworm fly (*Cochliomyia americana*).

SUMMARY

A review of the literature of animal parasites of the beaver is given, and the forms known to infect the beaver are listed. Evidence is presented which indicates that the fluke, *Paramphistomum castori* Kofoid and Park, 1937, is synonymous with *Stichorichis subtriquetrus*. Percentages of infection of 140 Minnesota-trapped beavers by four species of helminths are given.

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DIVISION OF ENTOMOLOGY AND ECONOMIC ZOOLOGY,
UNIVERSITY OF MINNESOTA,
AND
DIVISION OF GAME AND FISH,
MINNESOTA DEPARTMENT OF CONSERVATION,
ST. PAUL, MINNESOTA.

New Species and Notes on the Arrenuri

Ruth Marshall

Over seventy species of Arrenurus, the largest genus of the hydracarina (water mites), have been described for North America, chiefly from collections made in the north-east central parts of the United States and southern Canada. Yet up to the present time no representative of the Subgenus *Truncaturus* has been reported (Marshall 1940:137). The present paper records the finding of a new species, *A. kenki* belonging to this subgenus. Also included are descriptions of two other new species and additional notes on a third species, representing two other subgenera.

In the fall of 1941 Mr. C. H. Lavers visited localities in Alberta and British Columbia near the International Boundary from which had been secured the material for the first published account of species of Arrenurus for North America. These specimens, with other water mites, were sent to Dr. F. Koenike for identification. The results of this study were published (Koenike, 1895:167-226) and part of the collection returned to Ottawa for deposit. These specimens were mounted on slides but some have deteriorated. Also, since Koenike's drawings are somewhat diagrammatic certain points of identification have been in doubt. In the hope of finding the Koenike species, Lavers collected a large number of hydracarina. Among them he believed that he had found the four Arrenuri described. In this opinion the present author concurs. One species, *A. krameri,* has already been reported upon (Marshall, 1908:109); it was found by Lavers in small pools near the town of Pincer Creek, Alberta, as were also *A. lautus* and the two remaining species. Of the latter, one of them, *A. interpositus,* was first described from one immature male; mature males described as *angustocaudatus* (Marshall, 1908:116) are now believed to be Koenike's species and hence the later name becomes invalid. Lastly, the fourth species, *A. setiger,* is now identified with *A. ovalis* (Marshall, 1908:90), which name becomes a synonym.

Arrenurus (Truncaturus) kenki n. sp.

Pl. 1, Fig. 1, 2, 6

The body of the male is 0.67 mm. long; the greatest width, in the region of the 4th epimera, is 0.46 mm. The female is unknown. The color in preserved material is pale orange magenta with magenta appendages. The anterior outline is slightly convex, the body moderately elevated with no large humps. The dorsal enclosed area is large; the ends of the furrow reach well beyond the genital area to end on the sides of the appendix. The latter is a little narrower than the body; the end shows slight scallops, anterior to which are two low dorsal humps in line with the ends of the dorsal furrow. The epimera are extensive, the 4th with a slightly concave inner median border. The acetabular

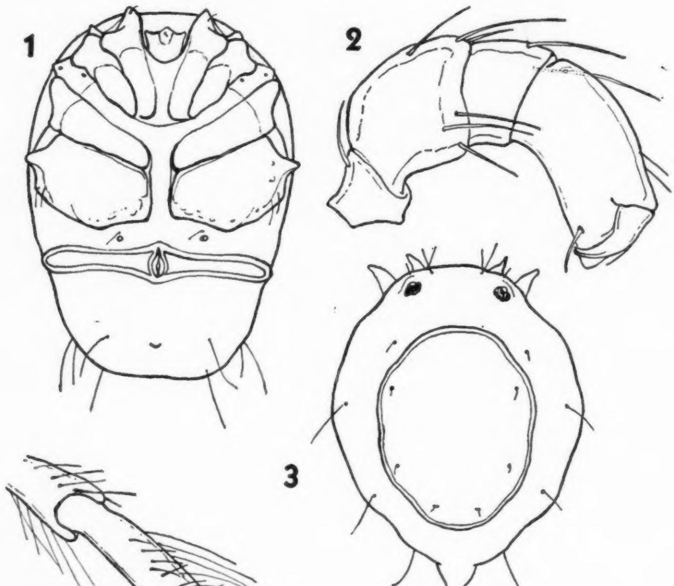


PLATE 1.—Figs. 1-2, *Arrenurus kenki*. 1, Ventral view, male. 2, Left palpus.
Fig. 3-5. *A. epimerosus*. 3, Dorsal view, female. 4, Leg IV, 4, 5, male. 5, Ventral view, female. Fig. 6. *A. kenki*, dorsal view, male.

plates are narrow and extend directly out from the genital openings to the body edge. In the palpus the 2nd segment has three large bristles on the inner median border with three others on the convex border; the 4th segment is the longest, of about the same width throughout. Leg IV has a small spur on the 4th segment.

This new species is the first reported record in North America for the Subgenus *Truncaturus,* characterized by a simple appendix or cauda which is hardly more than an extension of the body with no posterioı cleft and no petiole. It resembles *A. haplurus* (Viets 1925:549) found in Germany; the body is not as elongated, however, and it has a relatively smaller dorsal shield; the genital plates are narrower and extend farther out on the sides of the body, while the 2nd palpal segment has large bristles in place of a bunch of small ones.

Only one individual is known; this was found in a temporary pond near Ann Arbor, Michigan, by Mr. Roman Kenk, to whom the species is dedicated.

Arrenurus (Megaluracarus) laversi n. sp.

Pl. 2, Fig. 7-11; Pl. 3, Fig. 17

The length in the male is 1.10-1.15 mm.; the greatest width, just anterior to the center of the body, is 0.53 mm. The color in preservation is dull brick red. The anterior end is convex. The enclosed dorsal area is moderately elevated, with a low hump on either side in the region of the anterior end of the dorsal shield; the ends of the furrow run well over onto the ventral side of the appendix. The latter, about two-thirds as long as the body, is widest just anterior to the central region where it is also moderately elevated; there is a constriction near the end with two small elevations. The end of the appendix flares out and ends in shallow scallops. A small papilliform petiole (?) is sometimes found near the posterior end between two small guard hairs. The epimera are extensive, the three groups close together, with the posterior inner margin of the 4th pair concave. The acetabular plates are close to the epimera, wide, extending straight out from the genital opening, reaching only a little beyond the posterior angles of the last epimera. In the palpus all segments are stout; the 2nd has a group of three short hairs on the inner concave side and three long ones near the convex margin. This male resembles *A. prominulus* (Marshall, 1908:108), another west coast species; but both body and appendix are more slender, with the elevations on the latter less pronounced.

The female is ovate in form and largest specimens are 0.95 mm. long. The dorsal shield is large, elliptical in form. The epimera resemble those of the male but the three groups are more separated and the 4th pair relatively narrower. The acetabular plates are likewise broad, extending nearly straight out from the genital opening to a little beyond the posterior angles of the 4th epimera.

The author is indebted to the late C. H. Lavers for several specimens of this species which has been given his name; they were collected by him to the

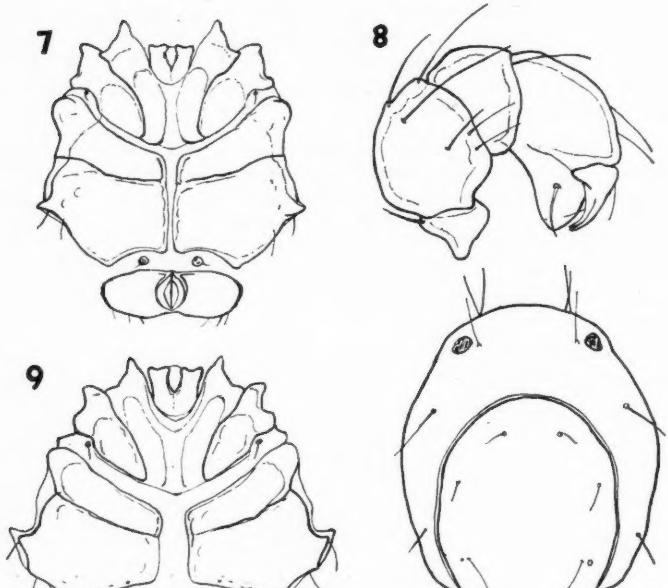


PLATE 2.—Figs. 7-11. *Arrenurus laversi.* 7, Ventral plates, male. 8, Left palpus, male. 9, Ventral plates, female. 10, Dorsal view, male. 11, Lateral view, male.

number of "a few hundred" in mountain waters near Seattle, Washington, in 1941.

ARRENURUS (MEGALURACARUS) EPIMEROSUS Mar.

Pl. 1, Fig. 3-5; Pl. 3, Fig. 18

The species was first described from the study of one male (Marshall, 1919:278); another male has since been found together with two females, so that the latter can now be described.

The female of *A. epimerosus* has an unusual form, the posterior end being prolonged to resemble the appendix of some males and ending in a large conical process. The entire length of the body is 0.60 mm.; the greatest width, in the center, is 0.45 mm. The anterior end is protruding, convex between the eyes as in the male. The dorsal shield is slightly obovate, the outline of the furrow wavy. The 1st pair of epimera have projecting inner anterior points; the 2nd are prolonged into horns in the same region and are nearly as large as in the male. The acetabular plates are directed diagonally back from the genital opening.

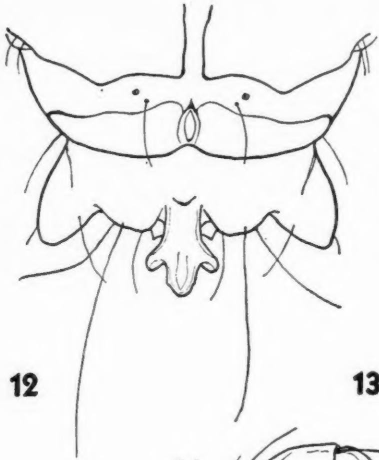
The palpus in the original drawing (Fig. 28) did not show all of the distinctive bristles of the 2nd segment; they were, however, correctly described by Viets (1936:280) who had also found the species in collections from Brazil. There are two short thin bristles on the inner side medially with two longer ones dorsal to them (Fig. 18).

The three specimens were found by Dr. Stillman Wright at Melancia, Guarany, Ceara, Brazil.

Arrenurus (Arrenurus) pleopetiolatus n. sp.

Pl. 3, Fig. 12-16

The male measures 1.12 mm. to the end of the petiole; the female is unknown. The color is blue green. The anterior end of the body is concave; the greatest width is in the region of the 4th epimera. The body is elevated in the lateral anterior third; near the base of the appendix there is a pair of large thorn-like elevations directed forward. The dorsal furrow runs over on the ventral side of the appendix, the ends lying on the posterior lateral projections. The appendix is highly developed; the lateral projections are large and directed strongly outward; between each and the petiole is a large double protuberance, each bearing two long hairs, with small humps medial to them. The petiole is very stout; from a heavy stem it flares out into a 3-divided part, the central piece largest and longest. The hyaline appendage is short, narrowed posteriorly, with the usaal pair of stout curved bristles at the base. The epimera are of the usual form, the 4th with a concave median border. The acetabular plates are broad near the genital opening, narrowing laterally to end on the sides of the body. The palpi are stout, the middle segments being broad, the 5th slim; on the 2nd segment are two heavy bristles on the inner distal side



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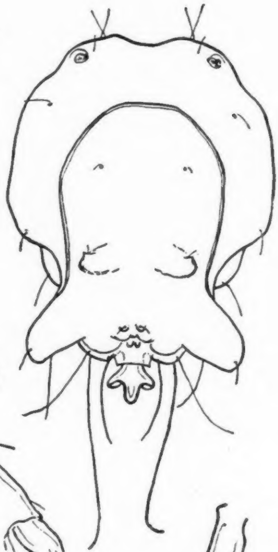

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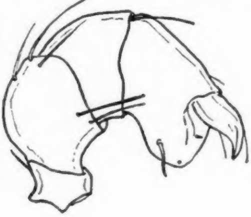

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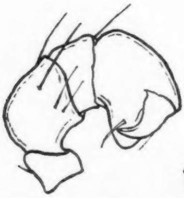

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PLATE 3.—Figs. 12-16. *Arrenurus pleopetiolatus.* 12, Appendix, ventral view. 13, Dorsal view, male. 14, Left palpus. 15, Leg IV, 4-6, male. 16, Lateral view, male.

Fig. 17, *A laversi*, dorsal view, female. Fig. 18, *A. epimerosus*, left palpus female.

Fig. 18, *A. epimerosus*, left palpus, female.

with three more near the lateral border. Leg IV has a well developed spur with a bunch of heavy hairs; the 5th segment is very short.

The new species bears some resemblance to *A. tacomaensis* (Marshall, 1924:213) in its general form with thorn-like dorsal processes; but the appendix has broader lateral processes and in the petiole the central projection is longer.

The specimen described was found in Three Sister Lake, near Ann Arbor, Michigan, by Dr. P. S. Welch, in 1927. Although many collections of water mites have been made in this general region, this is the only specimen of the new species known to the author.

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ROCKFORD COLLEGE,
ROCKFORD, ILL.

Contributions to a Synopsis of the Hemiptera of Missouri, Pt. III*

Lygaeidae, Pyrrhocoridae, Piesmidae, Tingididae, Enicocephalidae, Phymatidae, Ploiariidae, Reduviidae, Nabidae

Richard C. Froeschner

As before, this is to form a preliminary working basis for further study of these groups in the state by the author and others. Although some of the members of the groups here treated are represented by more complete records than were those in the earlier parts, there is still much work to be done on all of them.

My sincere thanks are due to Mr. H. G. Barber and Drs. C. J. Drake and H. M. Harris for authoritative assistance in the following families respectively: Lygaeidae, Tingididae and Nabidae. Drs. Drake and Harris also furnished us with a determined *Systelloderes biceps* for purposes of illustration. Mr. J. H. Evans named some of my specimens of Phymatidae.

Although my private collection formed the basis for this work, numerous records are included from the collections which were placed at my disposal by the following men: Drs. L. Haseman and E. P. Meiners and Messrs. W. S. Craig, J. A. Denning and W. R. Enns.

Records not my own are initialed to indicate the person responsible for them, as in the following list: C. M. Graham, C. W. Wingo, D. Eschenberg, E. H. Froeschner, E. P. Meiners, J. A. Denning, R. E. Roselle, R. I. Wakeman, W. R. Enns, W. S. Craig and W. W. Smith.

Again all the figures for the plates are the original work of my wife, Elsie Herbold Froeschner.

Keys to the Missouri Subfamilies, Tribes, Genera and Species of Lygaeidae

1. All sutures between the ventrals straight and reaching the side margins of the abdomen 2

   Suture between ventrals III and IV curved forward and not reaching side margins of the abdomen .... Subfamily *Rhyparochrominae* 15

2.(1). Hind margin of pronotum in front of scutellum turned down convexly; fore femora neither swollen nor spinose beneath 3

   Hind margin of pronotum not turned down; fore femora usually swollen and sometimes spined beneath 9

3.(2). Hemelytra and often entire upper surface impunctate .... Subfamily *Lygaeinae* .. 4

   Upper surface, except membrane, punctate .... Subfamily *Cyminae* 8

4.(3). Corium with apical margin straight; colors chiefly black and red .... Tribe *Lygaeini* 5

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* Parts I and II in this journal, **26**:122-146 and **27**:591-609.

Corium with apical margin distinctly sinuate near clavus; color not black and red .... Tribe *Orsillini* 6

5.(4). Pronotum with entire, longitudinal, median carina .... I. *Oncopeltus*
Pronotum without median carina .... II. *Lygaeus*

6.(4). Antennal I extending beyond apex of tylus; beak not surpassing first ventral....7
Antennal I not reaching apex of tylus; beak reaching or surpassing third ventral .... V. *Belonochilus*

7.(6). Eyes well removed from the front margin of the pronotum, the exposed space behind them more than one-half their diameter; costal margin of hemelytra straight throughout .... III. *Ortholomus*
Eyes contiguous or nearly so with the front margin of the pronotum; costal margins of hemelytra straight on basal fourth only........................ IV. *Nysius*

8.(3). Corium hyaline, no punctures along its middle; antennal IV slightly longer than III .... Tribe *Ischnorrhynchini* .... VI. *Ischnorrhynchus*
Corium opaque, punctate throughout; antennal IV shorter than III .... Tribe *Cymini* .... VII. *Cymus*

9.(2). At least ventrals I and II without visible spiracles 10
All ventrals with visible spiracles 13

10.(9). Head narrower than posterior margin of pronotum; tylus not sulcate; claval commissure at least half as long as scutellum..Subfamily *Blissinae*..11
Head across eyes as wide or wider than posterior margin of pronotum; tylus longitudinally sulcate; claval commissure very short or absent .... Subfamily *Geocorinae* 12

11.(10). Body elongate (Fig. 59), abdomen more than twice as long as head plus pronotum; hind margin of corium straight........................ VIII. *Ischnodemus*
Body short, oblong-oval (Fig. 58), abdomen less than twice as long as head plus pronotum; hind margin of corium sinuate near apex of clavus .... IX. *Blissus*

12.(10). Beak with segment I longer than II; head usually quite punctulate or rugulose .... X. *Geocoris*
Beak with segment I subequal to or shorter than II; head smooth, impunctate, shining .... XI. *Hypogeocoris*

13.(9). Fore femora strongly swollen and with rows of spines beneath; hemelytra not extending over sides of abdomen........Subfamily *Pachygronthinae*........14
Fore femora but slightly swollen and with but a single spine beneath; hemelytra extending beyond sides of abdomen .... Subfamily *Oxycareninae* .... XIV. *Crophius*

14.(13). Antennal I shortest, not reaching apex of tylus; head almost vertical........ .... XII. *Phlegyas*
Antennal I longest, surpassing apex of tylus; head nearly horizontal........ .... XIII. *Oedancala*

15.(1). Posterior glandular spot on fourth ventral closer to hind margin of that segment than to the front spot on the same segment 16
Posterior glandular spot on fourth ventral closer to front spot than to hind margin .... Tribe *Lethaeini* 34

16.(15). Pronotum with side margins of front lobe obtusely rounded........................ Tribe *Myodochini* 17
Pronotum with side margins of front lobe carinate or laminate-expanded........26

17.(16). Hind portion of head drawn out into a long slender neck which is longer than front lobe of pronotum (Fig. 61)........................ XV. *Myodocha*
Hind portion of head not so drawn out, although it may be somewhat neck-like 18

18.(17). Head not inserted into prothorax to eyes; anterior margin of pronotum with a ring-like collar 19

Head inserted into prothorax to eyes; pronotum without a ring-like collar......25

19.(18). Front lobe of pronotum never more than twice as long as hind one..........20
Front lobe of pronotum three or four times as long as hind one..........24

20.(19). Postocular space about four times that between eye and base of antenna ....XVI. *Heraeus*
Postocular space subequal to that between eye and base of antenna..........21

21.(20). Beak with segment I not reaching base of head; front and hind lobes of pronotum separated by a deep, clear-cut, transverse constriction..........22
Beak with segment I reaching base of head; front and hind lobes of pronotum separated by a shallow, obtuse constriction 23

22.(21). Ventrals II and III each with a lunate, strigose area either side of middle ....XVII. *Ligyrocoris*
Ventrals without strigose areas ....XVIII. *Orthaea*

23.(21). Hind tibiae with rigid bristles only; basal segment of hind tarsus fully three times as long as II plus III..........XIX. *Zeridoneus*
Hind tibiae with long setose hairs and a few bristles near apex; basal segment of hind tarsus not over twice the length of II plus III .... XX. *Perigenes*

24.(19). Anterior lobe of pronotum impunctate; ocelli absent..........XXIII. *Cnemodus*
Anterior lobe of pronotum sparsely punctate; ocelli present.......... XXIV. *Pseudocnemodus*

25.(18). Beak with segment I short, not or only slightly surpassing front margin of eyes ....XXII. *Sisamnes*
Beak with segment I longer, nearly or quite reaching base of head..........XXI. *Ptochiomera*

26.(16). Side margins of pronotum simply carinate; hind tibiae usually without rigid bristles..........Tribe *Rhyparochromini*..........27
Side margins of pronotum laminate-expanded; hind tibiae with rigid bristles..31

27.(26). Eyes not in contact with front margin of pronotum 28
Eyes in contact with front margin of pronotum..........29

28.(27). Front margin of pronotum with a distinct ring-like collar; hind tibiae with short, rigid bristles ....XXV. *Ozophora*
Pronotum without a collar on front margin; hind tibiae without rigid bristles ....XXVI. *Tempyra*

29.(27). Front lobe of pronotum black, hind one pale; scutellum with a V-shaped pale mark at apex ....XXVII. *Peritrechus*
Pronotum with both lobes concolorous; scutellum without pale mark..........30

30.(29). Head and pronotum not black, scarcely or not shining; pronotum trapezoidal, scarcely transversely constricted; antennal I equal to or slightly longer than width of head between eyes..........XXVIII. *Antillocoris*
Head and pronotum black, strongly shining; pronotum nearly parallel-sided, the transverse impression distinct; length of antennal I distinctly less than (about 2/3) width of head between eyes..........XXIX. *Cligenes*

31.(26). Antennals I, II and III without rigid bristles; narrowly expanded side margins of pronotum sparsely or not at all punctate..........Tribe *Beosini*..........32
All antennals with rigid bristles; widely expanded side margins and disk of pronotum and corium thickly punctate..........Tribe *Gonianotini*..........XXXIII *Emblethis*

32.(31). Upper surface not totally black 33
Upper surface wholly black ....XXXII. *Aphanus*

33.(32). Side margins of pronotum neither punctate nor setose; both lobes of pronotum black; scutellum without pale lines ....XXX. *Malezonotus*
Side margins of pronotum with a few punctures, each of which bears a

long seta; apical third of scutellum with a pale, oblique line either side of middle .... XXXI. *Sphragisticus*

34.(15). Pronotum with both lobes distinctly and closely punctate; antennae distinctly pilose .... XXXIV. *Drymus*

Front lobe of pronotum impunctate or with a few scattered punctures............ 35

35.(34). Pronotum longer than wide; head, front lobe of pronotum and scutellum black .... XXXV. *Eremocoris*

Pronotum wider than long; head, front lobe of pronotum and scutellum reddish-brown or brown............ XXXVI. *Cryphula*

I. *Oncopeltus* Stal

1. Coria orange-red with a broad, black band across their middles; length 13-18 mm. .... 138. *fasciatus* (Dall.)

II. *Lygaeus* Fabricius

1. Pronotum black with a red band across middle of posterior lobe; vertex marked with red 2

Pronotum without red band across basal lobe; head entirely black............ 4

2.(1). Clavus entirely black; membrane with margins and sometimes discal spots white; length 9.9-12 mm. .... 139. *kalmii* Stal (Fig. 56)

Clavus with basal half or more red 3

3.(2). Membrane wholly black; red spot of vertex Y-shaped, the anterior arms reaching to side margins of head; length 10-11.5 mm. .... 140. *turcicus* Fab.

Membrane with margins and sometimes discal spots white; red spot of vertex reduced, not approaching side margins of head............ 141. *reclivatus* Say

4.(1). Upper surface not pubescent; posterior lobe of pronotum red with hind margin narrowly yellow; length 7.5-9 mm. .... 142. *bicrucis* Say

Upper surface pubescent; posterior lobe of pronotum black with three pale spots on hind margin; length 3.4-4.5 mm. .... 143. *tripunctatus* (Dall.)

III. *Ortholomus* Stal

1. Head and pronotum nearly uniform brown; beak reaching on to second ventral abdominal segment; length 4.2-6 mm. .... 144. *scolopax* (Say)

IV. *Nysius* Dallas

1. Bucculae one-half the length of the head, evanescent posteriorly; antennal I distinctly surpassing apex of tylus; length 4.5-5.6 mm. .... 145. *californicus* Stal

Bucculae reaching base of head; width of head across eyes less than that of pronotum across base; antennal I but slightly surpassing apex of tylus; length 3.2-4 mm. .... 146. *ericae* (Schill.) (Fig. 57)

V. *Belonochilus* Uhler

1. Head, anterior portion of pronotum and scutellum with a pale, calloused median line; front femora with a small spine beneath at apical fourth; membrane with a vague reddish stripe at middle; length 5.3-6 mm. .... 147. *numensis* (Say)

VI. *Ischnorrhynchus* Fieber

1. Broadly oval; head and pronotum marked with black; length 4-5 mm. .... 148. *resedae* (Panz.)

VII. *Cymus* Hahn

1. Antennal I not surpassing apex of tylus and less than half the length of II; pronotum with no indication of median carina; length 3.8-4.2 mm. .... 149. *angustatus* Stal

Antennal I distinctly surpassing apex of tylus and half or more the length

of II; pronotum with a distinct median carina; length 4-4.5 mm. ....150. *virescens* (Fab.)

VIII. *Ischnodemus* Fieber

1. Beak not surpassing base of prosternum 2
Beak reaching middle of mesosternum; antennal IV one half longer than II; head and anterior portion of pronotum black; length 4.5-5.2 mm. ....153. *slossoni* VanD.

2.(1). Antennal II, III and IV subequal and black; membrane pale with fuscous veins; length 4.2-5.3 mm. ....151. *falicus* (Say)
Antennal IV one-half longer than II; beak with segment II not surpassing hind margin of eyes; membrane of brachypterous form (macropterous form not yet known) white, without veins; length 3.1-4.5 mm. ....152. *missouriensis* n. sp. (Fig. 59)

IX. *Blissus* Burmeister

1. Beak not surpassing middle coxae 2
Beak surpassing posterior margin of hind coxae; antennal IV more than twice the length of III; length 2.8-3.1 mm. ....157. *iowensis* André

2.(1). Antennae with apex of II and all of III and IV black; size larger, length more than 3.5 mm. 3
Antennae pale with only the apical segment black; size smaller, length 2.8 mm. ....156. *nanus* Barb.

3.(2). Antennal IV about three-fourths of II plus III; pronotum and scutellum finely and sparsely punctured; length 3.8-4.2 mm. ....154. *leucopterus* (Say) (Fig. 58)
Antennal IV as long as II plus III; pronotum and scutellum coarsely and densely punctured; length 4.7 mm. ....155. *validus* Blatch.

X. *Geocoris* Fallen

1. Head smooth, polished; sulcus of tylus extending back to vertex where it is crossed by a transverse sulcus; length 3.5-4.2 mm. ....158. *punctipes* (Say) (Fig. 60)
Head granulose; sulcus of tylus not extended; vertex without transverse sulcus 2

2.(1). Scutellum longer than wide, black, usually with an elongate, punctured yellow spot either side of middle; length 3-3.5 mm.................................... ....159. *bullatus* (Say) Scutellum as wide as long................................ 3

3.(2). Pronotum and corium coarsely, irregularly punctate, the latter with a large smooth area near middle; scutellum wholly black; length 3.5-4 mm. ....160. *uliginosus* (Say)
Pronotum and corium finely, evenly and shallowly punctate, the latter without smooth area; scutellum and upper surface pale grayish-yellow; length 3.1-3.3 mm. ....161. *frisoni* Barb.

XI. *Hypogeocoris* Montandon

1. Piceous, shining; head, beak and legs reddish-yellow or pale reddish-brown; length 4-4.2 mm. ....162. *piceus* (Say)

XII. *Phlegyas* Stal

1. Antennal II nearly three times length of I; membrane clouded witih fuscous; length 3-5 mm. ....163. *abbreviatus* (Uhl.) (Fig. 63)

XIII. *Oedancala* Amyot & Serville

1. Antennal I not more than two-thirds as long as II plus III; front femora shining black or piceous beneath; length 6-6.3 mm. ....164. *dorsalis* (Say)

XIV. *Crophius* Stal

1. Head, pronotum and scutellum piceous to dark fuscous-brown, hind lobe

of pronotum often paler; coria whitish-hyaline, membrane with a large fuscous, discal area; length 3-3.7 mm. .... 165. *disconotus* (Say)

XV. *Myodocha* Latreille

1. Antennal IV wholly dark; corium brownish with pale costal margin; length 8-9.5 mm. .... 166. *serripes* Oliv. (Fig. 61)

XVI. *Heraeus* Stal

1. Black with hind lobe of pronotum and corium dark reddish-brown; membrane brown with veins paler; antennal IV unicolorous; length 4.5-5.5 mm. .... 167. *plebejus* Stal.

XVII. *Ligyrocoris* Stal

1. Corium with narrow costal margin wholly pale; length 7.5-8.5 mm. .... 168. *obscurus* Barb.

   Corium with pale costal margin interrupted just behind middle by a transverse dark bar 2

2.(1). Transverse dark bar not reaching costal edge of corium; membrane with veins only pale, no apical pale spot; length 5-7 mm. .... 169. *diffusus* (Uhl.)

   Transverse dark bar reaching costal edge of corium; membrane with a large, distinct pale spot at apex; length 4.5-5.5 mm. .... 170. *sylvestris* (Linn.)

XVIII. *Orthaea* Dallas

1. Costal margin, except apex, wholly pale, not interrupted behind middle by a transverse black band 2

   Pale costal margin interrupted behind the middle by a transverse black band.. 3

2.(1). Corium without a pale spot at inner apical angle; form elongate; length 5.7-6.8 mm. .... 171. *longulus* (Dall.)

   Corium with an oval, pale spot at inner apical angle; form oblong-oval; length 3.8-4.2 mm. .... 172. *basalis* (Dall.) (Fig. 62)

3.(1). Antennal IV wholly fuscous; general color dark reddish-brown or fuscous; front of head declivent; length 4.8-5.3 mm. .... 173. *bilobata* (Say)

   Antennal IV broadly pale at base; general color pale reddish-brown; head porrect; length 5-5.3 mm. .... 174. *servillei* (Guer.)

XIX. *Zeridoneus* Barber

1. Head, front lobe of pronotum, scutellum and under side dull black; corium with costal margin and an obscure spot at inner apical angle pale; hind lobe of pronotum coarsely and sparsely punctate; length 6.5-8 mm. .... 175. *costalis* (VanD.)

XX. *Perigenes* Distant

1. Antennal II subequal to or slightly shorter than IV; length 5.4-6.5 mm. .... 176. *similis* Barb.

   Antennal II one-fifth longer than IV; length 7-8.5 mm. .... 177. *constrictus* (Say)

XXI. *Ptochiomera* Say

1. Dorsum densely clothed with long, erect pubescence; antennals I-III slender, cylindrical, IV slightly thicker, fusiform; color reddish-brown with antennae, beak and legs slightly paler; length 2.8-3.1 mm. .... 179. *puberula* Stal

   Dorsum glabrous; antennae strongly clavate, III and IV greatly thickened, III thicker than IV; antennals III and IV and front lobe of pronotum and scutellum shining black, strongly contrasting with the general straw-yellow color; length 3-3.5 mm. .... 178. *nodosa* Say (Fig. 65)

XXII. *Sisamnes* Distant

1. Antennal II longer than III, III and IV not strongly thickened, their greatest width less than twice that of II at apex; color reddish-brown with legs and hemelytra paler; length 2.8-3 mm. ....181. *antennata* VanD.

   Antennal II shorter than III, III and IV strongly thickened, their diameters at least twice that of II at apex; color fuscous to black with base of coastal margin, apex of femur, and broad band on middle of tibia pale yellow; length 2.5-2.8 mm. ....180. *clavigera* (Uhl.)

XXIII. *Cnemodus* Herrick-Schaeffer

1. Legs not hirsute with long hairs; black with antennae and legs brownish; length 8-9 mm. ....182. *mavortius* Say

XXIV. *Pseudocnemodus* Barber

1. Dark reddish-brown, shining; hind lobe of pronotum and hemelytra paler, the latter with costal margin pale yellow; legs yellow with apical half of front femora darker; length 5.5-6 mm. ....183. *canadensis* (Prov.)

XXV. *Ozophora* Uhler

1. Antennal IV with a broad, pale ring; hemelytra with an interrupted, transverse fascia behind the middle, and with a distinct pale spot at inner apical angle; length 6-6.5 mm. ....184. *picturata* Uhl.

XXVI. *Tempyra* Stal

1. Side margins of pronotum strongly carinate and reflexed; hemelytra yellowish-brown, piceous toward apex of corium, the latter with a large, prominent, subapical pale spot; length 3-3.5 mm...............185. *biguttula* Stal

XXVII. *Peritrechus* Fieber

1. Antennal I surpassing apex of tylus by half its length; vertex with coarse and fine punctures intermixed; length 4.3-5 mm. ....186. *fraternus* Uhl. (Fig. 66)

XXVIII. *Antillocoris* Kirkaldy

1. Upper surface thickly pilose with long yellow hairs; brachypterous form with membrane absent; length 1.8-2 mm. ....187. *pilosulus* (Stal)

   Upper surface thinly pilose with very short hairs; membrane always present; length 1.8-2.2 mm. ....188. *pallidus* (Uhl.)

XXIX. *Cligenes* Distant

1. Piceous black, with basal antennal segments, hemelytra, legs and apex of beak yellowish; pronotum with front lobe finely punctate anteriorly to impunctate disk and with disk of hind lobe sparsely and finely punctured; length 1.6 mm. ....189. *delineata* Dist.

XXX. *Malezonotus* Barber

1. Head, pronotum, except narrow side and hind margins, scutellum and under surface dull black; corium brownish-yellow with base of clavus and subapical blotch black; membrane fuscous, paler at base; length 4-5 mm. ....190. *sodalicius* (Uhl.)

XXXI. *Sphragisticus* Stal

1. Head, front lobe of pronotum, femora in part and under surface black; membrane brownish-yellow, the veins paler; length 5-5.3 mm. ....191. *nebulosus* (Fall.)

XXXII. *Aphanus* Laporte

1. Entire insect, including antennae and legs, black; length 6-7 mm. ....192. *umbrosus* (Dist.)

Antennae and legs in great part brownish-yellow; length 4.5-5.5 mm. ....193. *illuminatus* (Dist.) (Fig. 64)

XXXIII. *Emblethis* Fieber

1. Dull brownish-yellow, thickly marked with fuscous punctures; length 6-6.2 mm. ....194. *vicarius* Horv.

XXXIV. *Drymus* Fieber

1. Pronotal side margins slightly paler than disk; front lobe of pronotum darker and more finely punctate than hind one; length 4.2-5 mm. ....195. *unus* (Say)

   Pronotum entirely dark brown, the side margins not paler; both lobes evenly densely and coarsely punctate; length 6.5-7 mm. ....196. *crassus* VanD.

XXXV. *Eremocoris* Fieber

1. Pronotum disk of front lobe impunctate; femora not pilose; length 5.2-6 mm. ....197. *ferus* (Say) (Fig. 67)

   Pronotum with disk of front lobe finely and sparsely punctate, each puncture bearing an erect hair; femora thickly pilose with long erect hairs; length 7-7.5 mm. ....198. *setosus* Blatch.

XXXVI. *Cryphula* Stal

1. Narrow side margins of pronotum and corium and three elongate spots on apex of scutellum pale yellow; antennal I surpassing apex of tylus by one-third its length; length 3-4 mm. ....199. *parallelogramma* Stal

KEYS TO MISSOURI SUBFAMILIES, GENERA AND SPECIES OF PYRRHOCORIDAE

1. Sides of pronotum not margined............Subfamily *Euryophthalminae*............ 2

   Sides of pronotum strongly margined and reflexed; apical angle of corium acute ....Subfamily *Pyrrhocorinae*..........................III. *Dysdercus*

2.(1). Head triangular, narrower than width of pronotum; eyes stalked............. ....I. *Euryophthalmus*

   Head globular, convex above and beneath, subequal to width of pronotum; eyes sessile; anterior femora unarmed ....II. *Arhaphe*

I. *Euryophthalmus* Laporte

1. Corium dark with costal margin pale; membrane fuscous; ventrals black or piceous; length 14-17 mm. ....200. *succinctus* (Linn.) (Fig. 78)

II. *Arhaphe* Herrick-Schaeffer

1. Head and pronotum distinctly and coarsely punctate; membrane with basal two-thirds yellowish-white; length 8-10 mm. ....201. *carolina* H-S. (Fig. 77)

   Head and pronotum impunctate, the former finely rugulose; membrane wholly black; length 7.3-8.2 mm. ....202. *breviata* Barb.

III. *Dysdercus* Amyot & Serville

1. Antennae about four times the length of the pronotum and with segment I distinctly longer than II; corium black or brown with costal and apical margins narrowly pale; scutellum and femora red; length 12-17 mm. ....203. *suturellus* (H-S)

KEYS TO MISSOURI GENUS AND SPECIES OF PIESMIDAE

1. Antennal II ovoid, shorter than I; a double spine at inner angle of each eye; pronotum with antero-lateral margins narrowly but distinctly explanate ....I. *Piesma*

I. *Piesma* Lepeletier & Serville

1. Pronotum distinctly broader across the basal angles than across the apical

ones, the lateral margins emarginate and median carina distinct; length 2.7-3.3 mm. ....204. *cinerea* (Say) (Fig. 73)

KEYS TO MISSOURI TRIBES, GENERA AND SPECIES OF TINGIDIDAE

1. Front of pronotum with a bulbous, inflated hood; side margins of pronotum and hemelytra expanded laterally 2
   Front part of pronotum without an inflated hood; side margins of pronotum but slightly expanded laterally..................Tribe *Physatocheilini*.................. 6

2.(1). Hemelytra with discoidal area confined to basal half; osteolar openings (in our species) present, distinct...................Tribe *Galeatini*....................... 3
   Hemelytra with discoidal area reaching apical third or fourth; osteolar openings absent; pronotum tricarinate, the lateral ones sometimes indistinct ....Tribe *Acalyptini*.................................V. *Acalypta*

3.(2). Pronotal hood extending completely over the head; lateral carinae of pronotum not extending forward to the hood 4
   Pronotal hood small, not extending completely over head; basal third of hemelytra without tumid elevations; antennal III slender 5

4.(3). Side margins of paranota and hemelytra with a fringe of distinct spines; costal margins of hemelytra in great part parallel.........................I. *Corythucha*
   Side margins of pronotum and hemelytra without spines; costal margins of hemelytra divergent from base ....II. *Stephanitis*

5.(3). Sternal ridges connected by a transverse carina between the meso and metasterna; costal margins broadly expanded, not parallel at base....... ....III. *Gargaphia*
   Sternal ridges not connected by a transverse carina; pronotum tricarinate, the carinae reaching the hood; costal margins of hemelytra subparallel at base, sinuate or narrowed at or behind the middle..............IV. *Leptopharsa*

6.(1). Pronotum tricarinate, the median one sometimes elevated in front 7
   Pronotum unicarinate; antennals I and II subequal in length......XII. *Leptoypha*

7.(6). Paranota very wide, reflexed and lying flat against the dorsal surface of the pronotum; costal area of hemelytra with two or three rows of cells.... ....VI. *Physatocheila*
   Paranota narrow, when reflexed not covering any of the dorsal surface of the pronotum 8

8.(7). Beak reaching to or beyond the middle coxae; head with three to five distinct spines 9
   Beak not surpassing front coxae; head without spines but with a small, median tubercle ....XI. *Atheas*

9.(8). Antennal III slender and cylindrical to near apex where it is strongly and suddenly enlarged; reflexed paranota as high as the pronotal carinae ....VII. *Melanorhopala*
   Antennal III not thickened at apex; reflexed paranota not as high as the pronotal carinae 10

10.(9). Antennal III cylindrical throughout ....VIII. *Teleonemia*
   Antennal III gradually thickened from base and densely clothed with short, decumbent setae 11

11.(10). Hemelytra convex, the areas not or only very faintly delimited by costate veins ....IX. *Alveotingis*
   Hemelytra flattened, the areas distinctly limited by costate veins ....X. *Hesperotingis*

I. *Corythucha* Stal

1. Pronotal hood nearly or quite three times as high as median carina; paranota with a large, dark brown blotch on outer half; hind margin of

apical hemelytral cross-bar straight; length 3.5 mm.....205. *cydoniae* (Fitch)
Pronotal hood not more than twice as high as median carina 2

2.(1). Costal areas without dark cross-bars; cells of globose portion of hood larger than those of paranota 3
Costal areas with at least a well-marked, dark, basal cross-bar 4

3.(2). Color above milky white with a fuscous spot on tumid elevation of hemelytra; length 3.7 mm. ....206. *ciliata* (Say) (Fig. 69)
Color above pale yellowish-hyaline with no fuscous marks on hemelytra; length 3.8-4 mm. ....207. *pallida* O. & D.

4.(2). Side margins of paranota and hemelytra almost devoid of spinules; length 3.5 mm. ....208. *mollicula* O. & D.
Side margins of paranota and hemelytra with numerous distinct spines.......... 5

5.(4). Hemelytra with two more-or-less distinct dark, apical cross-bars and with cells milky-white, only their centers hyaline; length 3.2-3.4 mm. ....209. *marmorata* (Uhl.) (Fig. 70)
Hemelytra with a single preapical dark cross-bar or none 6

6.(5). Hood very little higher than median carina 7
Hood nearly twice as high as median carina 8

7.(6). Apical hemelytral cross-bar ill-defined (absent in var. *mali* Gib.) and occupying only the apical fourth; paranota with small dark spot or none; length 3-3.7 mm. ....210. *arcuata* (Say)
Apical hemelytral cross-bar well-defined, occupying apical third; paranota with a distinct dark spot; length 4-4.2 mm. ....211. *pruni* O. & D.

8.(6). Hemelytra without an apical cross-bar; median pronotal carina feebly arched; length 3.3 mm. ....212. *ulmi* O. & D.
Hemelytra with both basal and apical dark cross-bars. 9

9.(8). Larger, 4-4.2 mm; front of hood nearly vertical; hemelytra cross-bars dark fuscous brown, the apical one enclosing two or three large hyaline cells ....213. *aesculi* O. & D.
Smaller, not over 3.7 mm.; front of hood oblique or declivent..........................10

10.(9). Hemelytral cross-bars pale brown, the anterior one extending forward to basal margin; median pronotal carina lower than tumid elevation of hemelytra; length 2.8-3 mm. ....214. *pergandei* Heid
Hemelytral cross-bars dark brown, the anterior one separated from the basal margin; median pronotal carina as high as or higher than tumid elevation of the hemelytra. 11

11.(10). Cells of apical half of hemelytra small, whitish, subopaque; front margin of apical cross-bar not curved forward along sutural area; length 3-3.5 mm. ....215. *juglandis* (Fitch)
Cells of apical half of hemelytra large, clear hyaline; front margin of apical cross-bar curved forward along the sutural area; length 3.5 mm. ....216. *contracta* O. & D.

II. *Stephanitis* Stal

1. Hemelytra with a fuscous cross-bar at basal third and another at apical fourth, these connected by a curved fuscous stripe along each sutural area; antennae yellow, apex of IV fuscous; length 3.1-3.5 mm. ....217. *pyrioides* Scott

III. *Gargaphia* Stal

1. Head with basal spines long, visible in front of hood 2
Head with basal spines not extending beyond apex of hood; outer margin of paranota distinctly and sharply angled; antennal I dull yellow; length 3.3-3.5 mm. ....221. *angulata* Heid.

2.(1). Paranota broadly rounded with three or four rows of cells 3

Paranota angulately expanded and with five rows of cells at its widest part; antennal I black; length 4-4.2 mm. .... 220. *solani* Heid. (Fig. 71)

3.(2). Hood slightly lower than median carina; hemelytral discoidal area with apical angle distinctly acute and at its middle; length 4.2-4.8 mm. .... 218. *tiliae* (Walsh)

Hood slightly higher than median carina; hemelytral discoidal area with apical angle nearly a right angle and laterad of its middle; length 4.2-4.5 mm. .... 219. *amorphae* (Walsh)

IV. *Leptopharsa* Stal.

1. Hemelytra widest at basal third and with a premedian dark bar across costal area; antennal I twice as long as II; length 2.1-2.3 mm. .... 222. *clitoriae* (Heid.)

Hemelytra not widest at basal third and without a premedian cross-bar on costal area; antennal I three times as long as II. 2

2.(1). Hemelytra with nervures of costal area white; basal third of costal area with a single row of cells; length 2.7-2.8 mm. .... 223. *oblonga* (Say)

Hemelytra with nervures of costal area fuscous or brown; basal half or more of costal area with an outer row of large cells and an inner row of smaller ones; length 3-3.2 mm. .... 224. *heidemanni* O. & D.

V. *Acalypta* Westwood

1. Hemelytra with costal area containing a single row of cells except near base and apex; bucculae separated anteriorly; antennal III nearly four times as long as IV; length 2.3-3 mm. .... 225. *lillianis* Bueno

VI. *Physatocheila* Fieber

1. Beak not surpassing apex of rostral sulcus 2

Beak surpassing apex of rostral sulcus and attaining second ventral; costal area with two or three irregular rows of cells; length 3.3-4 mm. .... 228. *variegata* Parsh.

2.(1). Antennal III not enlarged apically; costal area of hemelytra with two regular rows of cells; length 3-3.5 mm. .... 226. *plexa* (Say)

Antennal III enlarged apically; costal area of hemelytra with two or three confused rows of cells; length 4.5-4.7 mm. .... 227. *major* O. & D.

VII. *Teleonemia* Costa

1. Antennal III almost twice as long IV; beak attaining front edge of metasternum; length 3.2-3.6 mm. .... 229. *nigrina* Champ.

Antennal III nearly four times as long as IV; beak reaching on to abdomen; length 4-4.5 mm. .... 230. *cylindricornis* Champ.

VIII. *Melanorhopala* Stal

1. Antennae clavate; paranota vertical, not reflexed against the disk of the pronotum; costal area of hemelytra with a single row of cells; length 5-6 mm. .... 231. *clavata* Stal

IX. *Hesperotingis* Parshley

1. Costal row of hemelytra with but a single row of cells; beak reaching hind coxae 3.7 mm. .... 232. *antennata* Parsh.

X. *Alveotingis* Osborn and Drake

1. Antennae short, subequal to length of pronotum along the median line; the areas of hemelytra not at all indicated by costate veins; length 2.1 mm. .... 233. *brevicornis* O. & D.

XI. *Atheas* Champion

1. Antennal III with basal fourth or more black; cross nervures of costal

area blackish at inner end; subcostal area with two rows of cells 2

Antennal III with only very extreme base black; cross nervures of costal area wholly pale; subcostal area with three rows of cells; length 2.6 mm. .... 235. *austroriparius* Heid.

2.(1). Antennae shorter than distance from apex of head to tip of triangularly prolonged hind margin of pronotum; beak reaching front coxae; length 2.2-2.5 mm. .... 234. *mimeticus* Heid. (Fig. 68)

Antennae slightly longer than distance from apex of head to tip of triangularly produced hind margin of pronotum; beak reaching middle coxae; length 2.4 mm. .... 236. *annulatus* O. & D.

XII. *Leptoypha* Stal

1. Hemelytra widest across discoidal area; costal margin in part with two rows of cells and flattened and reflexed 2

Hemelytra but slightly widened across discoidal area; costal margin narrow and deflexed; length 2.7-2.9 mm. .... 239. *mutica* (Say)

2.(1). Costal margin with two rows of cells on basal third only; antennal III twice as long as I plus II; length 2.7-2.9 mm. .... 237. *costata* Parsh.

Costal margin with two rows of cells extending to apical fourth; antennal III more than three times I plus II; length 2.8-3 mm. ......238. *elliptica* McA.

KEYS TO MISSOURI GENUS AND SPECIES OF ENICOCEPHALIDAE

1. Discal cell open; front coxal cavities open behind; front tarsi 1-segmented, mid and hind tarsi 2-segmented; posterior lobe of head subglobose .... I. *Systelloderes*

I. *Systelloderes* Blanchard

1. Antennal III subequal to either II or IV; hind margin of pronotum straight, not emarginate; brachypterous; length 3.8 mm. .... 240. *terrens* Drk. & Harr.

Antennal III one-third longer than either II or IV; hind margin of pronotum deeply, angulately emarginate; macropterous; length 3-4 mm. .... 241. *biceps* (Say) (Fig. 74)

KEYS TO MISSOURI SUBFAMILIES, GENERA AND SPECIES OF PHYMATIDAE

1. Scutellum short and triangular; front tarsi small .... Subfamily *Phymatinae* .... I. *Phymata*

Scutellum elongate, covering most of the hemelytra and reaching almost or quite to the apex of the abdomen; front tarsi absent .... Subfamily *Macrocephalinae* .... II. *Macrocephalus*

I. *Phymata* Latreille

1. Femora and most of venter black; connexival angles projecting prominently; length 5-6.5 mm. .... 242. *vicina* Handl.

Femora and most of venter pale; length 7 mm. or more 2

2.(1). Posterior lateral angles of connexivals I-III produced as distinct, prominent tubercles (Fig. 75); length 8-10 mm. .... 243. *fasciata georgiensis* Melin. (Fig. 75)

Posterior lateral angles of connexivals not tuberculate, occasionally projecting slightly as a simple angle .... 244. *pennsylvanica* Handl.

a. Male with antennal IV at least one-and-one-third times as long as II plus III; female with antennal IV subequal to II plus III; length 7-7.5 mm. .... 244. *p. pennsylvanica* Handl.

b. Male with antennal IV subequal to or slightly longer than II plus

plus III; female with antennal IV much shorter than II plus III; length 8.7-9.2 mm. ....244a. *p. americana* Melin

II. *Macrocephalus* Swederus

1. Scutellum coarsely punctate throughout; anterior half and lateral edges of pronotum with small round granules; length 5-5.5 mm. ....245. *prehensilis* (Fab.)

KEYS TO MISSOURI GENERA AND SPECIES OF PLOIARIIDAE

1. Head without tubercles or spines 2
   Head with two tubercles, one between the bases of the antennae, the other just beneath it and decurved above base of beak ....III. *Metapterus*

2.(1). Front tibiae nearly as long as the front femora; front femora armed beneath throughout their entire length ....I. *Empicoris*
   Front tibiae less than one-half as long as front femora; front femora armed below on apical half only ....II. *Emesaya*

I. *Empicoris* Wolff

1. Pronotum with an erect, median, black tubercle on the hind margin; length 4.5-5 mm. ....246. *tuberculatus* (Banks)
   Pronotum without median tubercle on hind margin; hind lobe of pronotum with lateral carinae obsolete at middle; length 5-5.5 mm. ....247. *rubromaculatus* (Blkbn.)

II. *Emesaya* McAtee & Malloch

1. Dark brown with apex of antennal I, apices of all femora and subapical ring on mid and hind one pale; length 33-37 mm.........248. *brevipennis* (Say)

III. *Metapterus* Costa

1. Pale stripe on venter of head equal to interocular width 2
   Pale stripe on venter of head distinctly narrower than interocular width; color dark fuscous brown; dorsum of abdomen reticulately rugulose; length 7-10 mm. ....251. *uhleri* (Banks) (Fig. 72)

2.(1). Middle and hind femora each with several brown rings; median carina of mesonotum faintly indicated; length 11-14 mm. ....249. *annulipes* (Stal)
   Middle and hind femora each with but a single dark ring; median carina of mesonotum distinct; length 13-15 mm. ....250. *fraternus* (Say)

KEYS TO MISSOURI SUBFAMILIES, TRIBES, GENERA AND SPECIES OF REDUVIIDAE

1. Ocelli absent; tarsi 3-segmented; scutellum ending in a long, horizontal spine; body length less than 8 mm. .....Subfamily *Saicinae*....I. *Oncerotrachelus*
   Ocelli present; length 10 mm. or more 2

2.(1). Hemelytra without a quadrangular or discoidal cell at inner basal angle of membrane; front and usually middle tibiae ending beneath in a concave spongy plate 3
   Hemelytra with a quadrangular or discoidal cell at inner basal angle of membrane (Fig. 83); tibiae simple 6

3.(2). Ocelli posterior to an imaginary line connecting hind margins of eyes; antennal II simple 4
   Ocelli anterior to imaginary line connecting hind margins of eyes; antennae remote from eyes; antennal II composed of numerous very small segments........................Subfamily *Hammacerinae*........................XIII. *Hammacerus*

4.(3). Apex of scutellum simple or produced as a single spine 5
   Apex of scutellum broad, with two or three simple spines.. ....Subfamily *Ectrichodiinae*........................XII. *Rhiginia*

5.(4). Pronotum with transverse constriction anterior to its middle; outer side of front coxae convex..........Subfamily *Reduviinae*.......... 12

Pronotum with transverse constriction posterior to its middle; outer side of front coxae concave..........Subfamily *Piratinae*.......... 13

6.(2). Ocelli farther apart than the inner margins of the eyes.......... ....Subfamily *Apiomerinae*..........XIV. *Apiomerus*

Ocelli nct as far apart as the inner margins of the eyes 7

7.(6). Head with front lobe longer than hind one........Subfamily *Stenopodinae*........ 8

Head with front lobe not longer than hind one........Subfamily *Zelinae*........15

8.(7). Head armed below and behind eyes with one or more branched or bifid spines 9

Head unarmed below and behind eyes or with simple spines..........10

9.(8). Antennal I produced beyond insertion of II; front femora spined below on both margins ....II. *Pnirontis*

Antennal I not produced beyond insertion of II; front femora unarmed beneath ....III. *Pygolampsis*

10.(8). Ocelli not or only slightly elevated; head gradually constricted behind eyes ....IV. *Stenopoda*

Ocelli distinctly elevated on a tubercle; head strongly narrowed into a slender neck 11

11.(10). Front femora swollen, armed beneath with short spines ....V. *Oncocephalus*

Front femora very slightly swollen, unarmed beneath ....VI. *Narvesus*

12.(5). Antennae inserted on top of head and close to front margins of eyes........ ....VII. *Reduvius*

Antennae inserted on sides of head and much in front of eyes....VIII. *Triatoma*

13.(5). Middle tibiae with a spongy plate at apex; ocelli narrowly separated..........14

Middle tibiae without a spongy plate at apex; ocelli widely separated........ .... XI. *Sirthena*

14.(13). Tibiae with spongy plates short, but half their length..........IX. *Melanolestes*

Tibiae with spongy plates long, extending nearly to base ....X. *Rasahus*

15.(7). Sides of mesosternum without a small tubercle or fold anteriorly near hind angles of prosternum..........Tribe *Zelini*..........16

Sides of mesosternum with a small tubercle or fold anteriorly near hind angles of prosternum..........Tribe *Harpactorini*..........22

16.(15). Beak with segment I shorter than II 17

Beak with segment I as long or longer than II 19

17.(16). Front femora as long as hind femora..........XV. *Zelus*

Front femora shorter than hind femora..........18

18.(17). Legs and antennae not annulated with black and yellow; beak with segment I not longer than head in front of eyes..........XVI. *Rhynocoris*

Legs and antennae distinctly annulated with black and yellow; beak with segment I distinctly longer than portion of head in front of eyes.......... .... XVII. *Pselliopus*

19.(15). Hind lobe of pronotum armed on disk with four prominent spines..........20

Hind lobe of pronotum unarmed on disk or armed with only two short, conical tubercles; apex of femora not spinose ....XXI. *Fitchia*

20.(19). Apical angles of ventrals III-V not prolonged 21

Apical angles of connexivals III-V prolonged backwards into distinct spines; jugae with an erect, short, acute tooth.......... XX. *Atrachelus*

21.(20). Head (viewed laterally) gradually tapering posteriorly into a neck; jugal spines pale, their length less than half the interocular width.......... .... XVIII. *Rocconota*

Head (viewed laterally) suddenly constricted posteriorly into a neck; jugal spines black, their length nearly as great as interocular width........ .... XIX. *Repipta*

22.(15). Front femora neither thickened nor spinose; pronotum produced back over scutellum as a high, median, tuberculate arch .... XXII. *Arilus*

Front femora distinctly swollen and spined; pronotum not so produced........23

23.(22). Front tibiae unarmed; front femora without dorsal, subapical, erect spines .... XXIII. *Acholla*

Front tibiae armed ventrally with long spines; front femora each with a dorsal, stout, subapical spine .... XXIV. *Sinea*

I. *Oncerotrachelus* Stal

1. Dull reddish- or yellowish-brown; hemelytra in great part, scutellum and middle of hind pronotal lobe fuscous brown; body, antennae and legs thickly clothed with fine, erect hairs; length 5.5-6.5 mm. .... 252. *acuminatus* (Say) (Fig. 85)

II. *Pnirontis* Stal

1. Antennal I with a row of spines beneath; front tibiae armed below with two rows of spines; connexival incisures maculate with fuscous; length 11-13 mm. .... 253. *modesta* Banks

III. *Pygolampsis* Germar

1. Antennal I about one-half as long as head; front femora strongly swollen; length 13-15 mm. .... 254. *sericea* Stal.

Antennal I slightly longer than head; front femora only slightly swollen; length 13-16 mm. .... 255. *pectoralis* (Say)

IV. *Stenopoda* Laporte

1. Dull straw-yellow, apex of clavus and blotch on hemelytral discal cell black; anterior femora not strongly swollen but armed beneath with two rows of short tubercles; length 20-22 mm. .... 256. *cinerea* (Lap.)

V. *Oncocephalus* Klug

1. Antennal II about two-and-one-half times as long as I, the latter over twice as long as the preocular margin to apex of antenniferous tubercle; length 14-15 mm. .... 257. *geniculatus* Stal

Antennal II about three times as long as I, the latter two-fifths longer than the preocular margin to apex of antenniferous tubercle; length 13-16 mm. .... 258. *apiculatus* Reut.

VI. *Narvesus* Stal

1. Dull straw-yellow with ocellar tubercle, scutellum, clavus, large blotch on hemelytral discal cell and an oblong mark on outer cell of membrane fuscous or black; tibiae not fasciate with black; length 13-17 mm. .... 259. *carolinensis* Stal (Fig. 83)

VII. *Reduvius* Fabricius

1. Nearly uniform piceous brown, apices of femora and apical halves of tibiae paler; hemelytra largely membranous; length 17-20 mm. .... 260. *personatus* (Linn.)

VIII. *Triatoma* Laporte

1. Surface of pronotum and prosternum more or less granulate; pronotum not marked with red; head fuscous .... 263. *rubrofasciata* (DeG.)

Surface of pronotum and prosternum without granules; pronotum with side margins marked with red 2

2.(1). Beak glabrous or nearly so, segment II twice or more as long as I; length 16-21 mm. .... 261. *sanguisuga* (Lec.) (Fig. 86)

Beak pilose with numerous long, inclined hairs, segment II only one-third longer than I; length 18-22 mm. ....262. *heidemanni* Neiva

IX. *Melanolestes* Stal

1. Abdomen entirely black; length 15-20 mm. ....264. *picipes* (H-S) (Fig. 82)
   Abdomen in part or entirely red; length 13-18 mm. ....265. *abdominalis* (H-S)

X. *Rasahus* Amyot & Serville

1. Pronotum shining black, the anterior lobe with seven distinct sulci; hemelytra dark brown, inner portion of basal half of corium as far as tip of clavus, apical half or more of clavus and large oval spot at base of membrane yellow; length 17-20 mm. ....266. *hamatus* (Fab.)

XI. *Sirthena* Spinola

1. Head, pronotum and scutellum black or piceous; corium pink with inner basal margin and clavus fuscous; length 18-25 mm. ......267. *carinata* (Fab.)

XII. *Rhiginia* Stal

1. Hemelytra fuscous, not reaching apex of abdomen; legs dull yellow, apical fourth of femora and tibiae brown or black; length 12-16 mm. ....268. *cruciata* (Say) (Fig. 87)

XIII. *Hammacerus* Laporte

1. Black, slightly shining; hemelytra with a broad, dirty-white cross-bar covering basal half or more; connexivum red with incisures narrowly black; basal half of hind femora red; length 22-30 mm. ....269. *purcis* (Dru.) (Fig. 88)

XIV. *Apiomerus* Laporte

1. Pronotum black with narrow margins red; corium blackish-brown, the extreme base pale; ventrals usually wholly black; length 14-19 mm. ....270. *crassipes* (Fab.) (Fig. 80)
   Pronotal disk and coria both in great part red; ventrals pale with basal and apical margins black; length 13-16 mm. ....271. *spissipes* (Say)

XV. *Zelus* Fabricius

1. Pronotum not spined on humeral angles nor on disk of hind lobe; antennae, hemelytra and legs pale, the latter not annulate with fuscous; length 11-14 mm. ....272. *cervicalis* Stal
   Humeral angles and sometimes disk of hind lobe of pronotum spined 2

2.(1). Humeral angles of pronotum with a prominent, outward-projecting spine; pronotal disk without spines, the hind lobe rugulose; length 15-17 mm. ....273. *exsanguis* (Stal)
   Humeral angles and disk of hind lobe of pronotum armed with tubercles or short spines; front lobe of pronotum piceous, hind one paler 3

3.(2). Femora each with a single, dark ring on apical half; length 13-15 mm. ....274. *socius* Uhl.
   Femora each with two dark rings on apical half; length 13-14 mm. ....275. *audax* Banks

XVI. *Rhynocoris* Hahn

1. Head, antennae, disk of hind lobe of pronotum, scutellum, sterna, sides of ventrals I-IV and legs, except coxae, shining black; front lobe of pronotum in great part, margins of hind lobe, coria and abdomen dull red; segment II of beak strongly compressed, as long as the others united; length 10.5-11.5 mm. ....276. *ventralis* (Say)

XVII. *Pselliopus* Bergroth

1. Pronotum with disk smooth; tibiae annulate throughout 2
   Pronotum with disk tuberculate; tibiae annulate only toward bases; length 11-11.5 mm. ....279. *latifasciatus* Barb.

2.(1). Basal margin of pronotum within wide emargination in front of scutellum, straight; color bright orange-yellow; length 12.5-14 mm. ....277. *barberi* Davis (Fig. 84)
   Basal margin of pronotum within wide emargination in front of scutellum, bisinuate; color dull yellow, clouded with fuscous; length 12-13 mm. ....278. *cinctus* (Fab.)

XVIII. *Rocconota* Stal

1. Pronotum with front lobe rugulose; apical angle of first connexival prolonged into a short spine; hemelytra wholly pale; length 16-20 mm. ....280. *annulicornis* (Stal)

XIX. *Repita* Stal

1. Color orange-red or yellow, hind lobe of pronotum with four stripes and spines black, corium and clavus fuscous or black, the costal margin pale; length 11-13 mm. ....281. *taurus* (Fab.)

XX. *Atrachelus* Amyot & Serville

1. Dull brownish-yellow, front lobe of pronotum darker; upper surface, except membrane, thickly covered with prostrate ash-gray pubescence; abdomen dull yellow, the sides usually with a blackish stripe; length 7-8 mm. ....282. *cinereus* (Fab.)

XXI. *Fitchia* Stal

1. Hind lobe of pronotum without tubercles or spines; hind lobe of head gradually tapering from eyes; length 12-14 mm. ....283. *aptera* Stal
   Hind lobe of pronotum with two short spines or tubercles on disk and one above each humeral angle; hind lobe of head suddenly constricted behind its middle; length 13-16 mm. ....284. *spinosula* Stal

XXII. *Arilus* Burmeister

1. Thickly clothed, except on membrane, with short, fine grayish pubescence; antennae, tibiae and tarsi reddish-brown; pronotal crest with eight to twelve tubercles; connexivum widely exposed; length 28-36 mm. ....285. *cristatus* (Linn.) (Fig. 81)

XXIII. *Acholla* Stal

1. Dull brownish-yellow or fuscous brown; legs and basal antennals vaguely annulate; pronotum with anterior lobe grooved and tuberculate and with hind one reticulate; length 12-16 mm. ....286. *multispinosa* (DeG.)

XXIV. *Sinea* Amyot & Serville

1. Pronotum spinose on disks of both lobes; front femora very strongly swollen, shining black and with apical spine of inner, inferior row out of alignment, occupying a subdorsal position; length 7.5-9.4 mm. ....287. *complexa* Caud.
   Pronotum with anterior lobe only bearing spines or tubercles, the hind one unarmed 2

2.(1). Pronotum with front lobe bearing distinct, erect spines; length 12-14 mm. ....288. *diadema* (Fab.)
   Pronotum with front lobe bearing short, blunt tubercles; connexival IV and basal halves of V and VI darker than the rest; length 12-15 mm. ....289. *spinipes* (H-S)

KEYS TO MISSOURI SUBFAMILIES, TRIBES, GENERA AND SPECIES OF NABIDAE

1. Pronotal collar absent or very narrow; antennae 5-segmented .... Subfamily *Prostemminae* .... I. *Pagasa*

Pronotal collar distinct, wide; antennae 4-segmented; ocelli present .... Subfamily Nabinae .... Tribe *Nabini* 2

2.(1). Antennal I less than twice as long as head, not thickened along apical third; middle tibiae armed along inner margin with short spines .... II. *Nabis*

Antennal I twice as long as head, suddenly and evenly thickened along apical third; middle tibiae unarmed .... III. *Metatropiphorus*

I. *Pagasa* Stal

1. Beak with segment II surpassing base of head; length 7.5 mm. .... 290. *pallipes* Stal

Beak with II not surpassing posterior margin of eye 2

2.(1). Head, anterior lobe of pronotum (except narrow collar), genital segment and sometimes last abdominal segment piceous black; rest of body and legs reddish-orange; legs without long hairs; length 5.2-6 mm. .... 291. *fasciventris* Harr.

Piceous black, posterior lobe of pronotum and hemelytra sometimes brownish, antennae, beak and legs yellow or reddish-yellow; legs with long hairs; length 6.8 mm. .... 292. *fusca* (Stein) (Fig. 79)

II. *Nabis* Latreille

1. Body shining black, with antennae, legs beak and connexival margins yellow; head strongly narrowed behind eyes; length 8-9.8 mm. .... 293. *subcoleoptratus* (Kby.)

Body in great part gray or brownish; head not narrowed behind eyes 2

2.(1). Tibiae annulate throughout; front and middle femora armed beneath with minute, blunt, piceous teeth; length of hairs of hind tibiae less than twice the diameter of hind tibiae 3

Tibiae annulate at base and apex only, or not at all; front and middle femora unarmed beneath or armed only with spine-like setae, never with short teeth 4

3.(2). Antennal I equal to or greater than width of head through eyes; under surface of abdomen pale with dark fuscous stripes along either side of middle; length 6.5-8 mm. .... 294. *sordidus* Reut.

Antennal I less than width of head through eyes; under surface of abdomen uniformly dark; length 6.3-6.9 mm. .... 296. *deceptivus* Harr.

4.(2). Femora each wiith a subapical black ring; antennal I about as long as pronotum, the latter with the hind lobe distinctly punctate; length 8-9.5 mm. .... 295. *annulatus* Reut.

Femora without subapical black rings; hind lobe of pronotum not punctate 5

5.(4). Head beneath in great part fuscous or black; hind tibiae with conspicuous fuscous spots; length 6.6-9.2 mm. .... 297. *roseipennis* Reut.

Head beneath nearly or quite entirely pale; hind tibiae immaculate or with small, fuscous dots 6

6.(5). Hemelytra shining, not speckled with fuscous between nervures; length 6.9-9.9 mm. .... 298. *capsiformis* Germ.

Hemelytra opaque, with numerous fuscous speckles between nervures 7

7.(6). Antennal IV about one-and-one-half times as long as I; length 6.3-7.3 mm. .... 299. *kalmii* Reut.

Antennal IV subequal to or shorter than I 8

8.(7). Pronotum, when viewed laterally (Fig. 76b), with the two lobes separated by a distinct constriction, the posterior lobe strongly elevated; length 7.5-8.1 mm. .... 300. *alternatus* Parsh.

a. Connexivum pale with basal half of each segment fuscous ....300. *a. alternatus* Parsh.

aa. Connexivum uniformly pale.................................300a. *a. uniformis* Harr.

Pronotum, when viewed laterally (Fig. 76a), with the two lobes separated by an obtuse constriction, the posterior lobe slightly elevated; length 7.2-9 mm. ....301. *ferus* (Linn.) (Fig. 76)

III. *Metatropiphorus* Reuter

1. Antennal II almost two-fifths longer than I; head, markings on anterior lobe of pronotum, scutellum, subapical ring on each femur and underside of body blackish; length 6.9-7.2 mm. ....302. *belfragii* Reut.

Annotated List of Species

LYGAEIDAE

138. *Oncopeltus fasciatus* (Dall.).—A common species that will undoubtedly be found throughout the state on *Apocynum* and *Asclepias*. The nymphs, which have been found during August, September and October, were nearly all collected from *Apocynum*, a very few on *Asclepias*. Adults have been found from May 8 until October 26. Atchison, Barry, Barton (RER), Boone, Cass, Cole, Cooper (WRE), Crawford, Greene (RER), Iron (EHF), Jasper, Lawrence (WWS), Maries, Miller, Mississippi, Morgan (EHF), New Madrid, Newton, Osage, Polk, Ste. Genevieve, St. Louis, Shannon (EHF) and Worth (RIW) counties.

139. *Lygaeus kalmii* Stal.—This very common milkweed bug will undoubtedly be found througout the state. Adults have been collected during every month of the year, hibernating singly or in congregations of as many as sixteen to twenty in grass clumps, under logs or rocks or among leaves on the ground. Two color forms, based on the intensity of the black portions and the amount of white on the membrane, have been listed as occurring in Missouri. However, these colors vary so in the material at hand that I have given up trying to separate them. Barber (1912) cites Montadon's (1893) description of the color form *melanodermus* from "St. Louis, Mo." VanDuzee (1917) records the species for the state. Parshley (1923) lists his color form, *angustomarginatus*, for "Missouri." Barry, Bates (WRE), Boone, Buchanan, Butler (EHF), Callaway (WRE), Camden, Carter, Cass, Chariton, Clark, Crawford, Dunklin, Gentry (EHF), Henry (EHF), Jackson, Jefferson, Lafayette, Lawrence (WWS), Linn, Macon, Maries, McDonald, Morgan (EHF), Newton, Oregon, Osage (EHF), Pettis (WRE), Pike (JAD), Pulaski, Ste. Genevieve, St. Louis, Saline, Shannon (EHF), Taney (EHF), Texas (EHF) and Vernon counties.

140. *Lygaeus turcicus* Stal.—A not uncommon milkweed-inhabiting species that will probably be found state-wide in its distribution. It is usually taken from the flowers of the butter-fly weed, *Asclepias tuberosa* L. Adults are at hand for the period from April 2 until September 10. The early records indicate that this insect will probably be found to pass the winter in the adult stage. Uhler (1876), Barber (1912), VanDuzee (1917) and Blatchley (1926) all list it for the state. Barry, Boone, Carter, Lawrence (WWS), Maries, St. Louis and Shannon counties.

141. *Lygaeus reclivatus* Say.—This species, which was described (1825) from "Missouri Territory" and subsequently listed for the state by VanDuzee (1917), has been found to be a western and southwestern species and so probably is not a member of our insect fauna. "Missouri Territory," as used by Say, involved most of the territory of the Louisiana Purchase, so it is quite possible that the types were collected well beyond the present confines of the state. As this now appears to be the case, we had better drop this name from our lists for the sake of greater accuracy.

142. *Lygaeus bicrucis* Say.—"Missouri" is given (1825) as the type locality for this species. It is rather common, usually being found at lights, but I have swept some from weedy fields and have found an occasional specimen running on the ground among the plants. Adults have been collected the year around. Uhler (1876) and VanDuzee (1917) both include Missouri among their records for this name. In several local collections this species has been placed under the name *Dysdercus suturellus,* the cotton-stainer—a pest that is as yet not known to occur in this state. Barry, Boone, Buchanan, Butler, Cole, Dent, Dunklin, Franklin (WRE), Iron, Lawrence (WWS), McDonald (EHF), Miller (WRE), Mississippi, Pemiscot, Pettis (WRE), Pike (JAD), St. Charles, St. Louis and Stoddard counties.

143. *Lygaeus tripunctatus* (Dall.).—Represented in available collections by two specimens taken at Columbia on May 5 (DE) and May 7 (WRE).

144. *Ortholomus scolopax* (Say). — Originally described (1832) from Missouri and Indiana as *Lygaeus scolopax,* this common species should occur throughout the state. It apparently prefers dry, upland fields. Adults have been found from June 8 to October 22. Uhler (1876) lists it for the state as *Orsillus scolopax.* VanDuzee (1917) records it for "Mo." under a synonym *O. longiceps* (Stal). Adair, Atchison (EHF), Audrain, Barry, Boone, Butler, Clark, Crawford, Daviess, Gentry, Howell, Macon (EHF), Mercer (EHF), Mississippi, Montgomery, Morgan, Nodaway, Oregon, Ozark, Pike (WSC), Pulaski, Scotland, St. Louis, Shannon, Stone, Taney, Vernon (WRE) and Washington counties.

145. *Nysius californicus* Stal.—An uncommon species that should occur throughout the state. Most adults at hand were collected either at lights or by sweeping in weedy fields between April 27 and October 29. It will probably be found to hibernate as an imago. Parshley (1922) lists it for "Missouri." Barry, Boone, Buchanan (CMG), Cole, Dunklin, Mississippi, Pemiscot and St. Louis counties.

146. *Nysius ericae* (Schill.).—A very common species of which a surprisingly small number of specimens are to be found in local collections. This is the "false chinch bug" which is so often listed as doing damage to field and garden crops. This insect should be found throughout the state, and although available Missouri records show it only from June 8 to November 4, it should occur the year around. Boone, Cass, Chariton, Cole, Harrison, Linn, Macon, Osage, Pulaski and Stoddard counties.

147. *Belonochilus numensis* (Say).—Near Bagnell on May 17 adults and nymphs were found feeding on *Ambrosia trifida* L. along a stream under sycamore trees. Knowing that this species had been taken from sycamore in other states, an attempt was made to find it on those trees. A very occasional adult and no nymphs were thus taken. However, nymphs and adults were swept in some numbers from *Celtis occidentalis* L. but no feeding was observed on this plant. One week later they were still present but in greatly reduced numbers. The next trip to this station, in mid June, found no specimens. A single specimen was taken at lights in Columbia on June 1, one was swept from sycamore near Longtown (Perry Co.) on August 23. Another was collected at New Hartford (Pike Co.) on December 7 (WSC). The remains of another specimen were found in a spider-web near Kennett (Dunklin Co.).

148. *Ischnorrhynchus resedae* (Panz.).—A scarce species that has been swept from weedy fields. Adults have been collected in March, April and May and again in August and September. VanDuzee (1917) records it for "Mo." under a synonym, *I. geminatus* (Say) which was described (1832) under the generic name *Lygaeus* from "Indiana and Missouri." Boone, Clark, Dunklin, Franklin, Morgan, Phelps and Pike (EHF) counties.

149. *Cymus angustatus* Stal.—Adults and nymphs have been collected commonly from various species of *Carex* and *Juncus*. It should occur throughout the state on those plants. Adults are at hand for the period from April 4 to November 16, the latter in grass clumps, so it should occur the year around. Nymphs were found in June, July and September. Audrain, Boone, Butler, Carter, Cass, Clark (EHF), Cooper (WRE), Dallas, Dent (EHF), Dunklin, Jasper, Jefferson, Lafayette, Lewis (EHF), Livingston, Macon, Miller, Mississippi, Montgomery, Morgan (WRE), New Madrid, Newton, Nodaway, Pemiscot, Perry, Phelps, Pike (WSC), St. Louis, Schuyler, Scott and Stoddard counties.

150. *Cymus virescens* (Fab.).—Numerous specimens have been swept from *Juncus* at Eminence (Shannon Co.), Longtown (Perry Co.), Portageville (New Madrid Co.) and Tyler (Pemiscot Co.). The dates of capture are May 10, August 11 and 23 and October 7 indicating that it will be found the year around, as is *C. angustatus*. Barber (1924) listed it for the state.

151. *Ischnodemus falicus* (Say).—This species was originally described (1832) from "Missouri" as *Lygaeus falicus*. It is commonly swept from grasses and sedges and is often found in association with chinch bugs on corn. Available records indicate adult occurrence as from May 7 to September 21, but it will probably be found the year around in this state as has been recorded for other states. Nymphs have been collected during June, July and September. Atchison, Boone, Cass (EHF), Gentry, Harrison, Jasper, Lewis, Livingston, Mercer, Miller, Morgan (WRE), Nodaway, Pike (WSC), St. Charles, St. Louis and Vernon counties.

152. **Ischnodemus missouriensis** n. sp. (Plate 6, Fig. 59).—Elongate, slender, typical *Ischnodemus* form. Black, thickly clothed above and below with minute, silver-gray pubescence, a little more sparsely so on head and

pronotum. Antennae slightly longer than head plus pronotum along the median line (42:39), its color variable from entirely black to reddish-brown with apical segment only black; segment I stout, two-thirds as wide as long; II almost twice as long as I; III slightly shorter than II; IV one-and-one-half times as long as II, the antennal formula being I:II:III:IV::6:11:9:17. Beak reaching between front coxae, segment II not reaching hind margin of eyes and so not attaining base of head. Pronotum with side margins parallel on basal half and rounded in front, the hind margin broadly, shallowly and arcuately concave; anterior lobe with an obsolete, longitudinal impression, the posterior lobe with a faint, impunctate, transverse impression before the polished posterior margin; basal ninth or tenth (on median line) of pronotum pale. Scutellum with a few distinct punctures, obsoletely carinate near acute apex. Brachypterous hemelytra (macropterous form not yet known) slightly shorter than length of pronotum and scutellum together and just attaining base of second tergite; slightly separated beyond apex of scutellum by a space equal to about one-twelfth of basal width of scutellum; corium dull yellow with apical and usually inner margin and frequently much of clavus infuscated; membrane opaque, milky-white, without veins. Legs reddish-brown, the femora swollen, more so on front pair, and unarmed. Osteolar auricle inconspicuously paler.

Female with oblique hind margin of fifth ventral coming together on midline posteriorly to hind margin of fourth segment.

Length 3.6-5.0 mm.

Holotype: U.S.N.M. No. 56501, male, Fisk (Butler Co.), Missouri, May 11, 1940 (R. C. Froeschner).

Allotype: female, same data as for holotype.

Paratypes: 1 male, Dudley (Stoddard Co.), Mo., May 4, 1941; 2 females, Fisk, Mo., May 11, 1940; 1 female, Dudley, Mo., August 12, 1941; and 1 female, Poplar Bluff (Butler Co.), Mo., May 4, 1941. Holotype and allotype have been deposited in the collection of the National Museum. Paratypes are in the author's collection.

This species is evidently closely allied to *hesperius* Parshley (another species known only in the brachypterous form) and with it is separable from all other described North American species by virtue of the short beak, long apical antennal segment, separated brachypterous hemelytra and milky-white membrane without veins. *Missouriensis* n. sp. can be separated from *hesperius* Parsh. by the following couplet:

Beak with segment II not reaching posterior margin of eyes; hemelytra narrowly separated beyond apex of scutellum by a space equal to about one twelfth of basal width of scutellum; basal margin on pronotum narrowly pale (about one-tenth of median length) .... *missouriensis* n. sp.

Beak with segment II surpassing hind margin of eyes and nearly or quite reaching base of head; hemelytra widely separated beyond apex of scutellum by a space greater than one-fourth basal width of scutellum; basal margin of pronotum broadly pale (about one-sixth of median length) .... *hesperius* Parsh.

Mr. H. G. Barber kindly compared my specimens with the *Ischnodemus* in the collection of the National Museum and verified its distinctness from them.

153. *Ischnodemus slossoni* VanD.—The single female of this species, identification of which was kindly checked by Mr. H. G. Barber, was swept from sedges in a drainage ditch near Fisk (Butler Co.) on May 11, 1941.

154. *Blissus leucopterus* (Say).—This is the common "chinch bug" of economic literature. Adults have been found the year around, nymphs appear first in June and are to be found from then until frost. In the active season adults and nymphs may be found on corn, wheat and other grains. Imagoes hibernate in enormous numbers in clumps of *Andropogon* and other grasses and under debris on the ground. VanDuzee (1917) lists it for Missouri in his "Catalogue." Dr. Leonard Haseman of the University of Missouri, who has worked on this pest in Missouri for many years, writes to me that on the basis of general correspondence and field experience he "would not hesitate to say that the common chinch bug is, and has been for years, present in every county and probably every township in the State of Missouri."

155. *Blissus validus* Blatch.—Originally described from Indiana, this species might possibly be found to occur in Missouri.

156. *Blissus nanus* Barb.—This species was described from two stations in Kansas, one of which, Garrett, is in the second tier of counties along the eastern or Missouri border of that state. Thus there appears to be fine probabilities of its occurring in this state.

157. *Blissus iowensis* André.—As its name implies, this species was described from Iowa. One specimen has also been recorded from Kansas so it will undoubtedly be found in at least the northwestern corner of Missouri.

158. *Geocoris punctipes* (Say).—Adults of this not uncommon species are to be found the year around. In summer they are taken principally by sweeping low weeds or by searching under objects on the ground. During the winter they hibernate under mullein leaves, rocks or other debris on the ground. Barry, Boone, Carter, Crawford, Dunklin (EHF), Mississippi, Oregon, Pemiscot, Perry (EHF), Pulaski, St. Louis, Stone and Wayne counties.

159. *Geocoris bullatus* (Say).—A scarce species, adults of which have been taken at lights and from weedy fields on July 1 and 15 and again in September on the 10th, 20th and 27th. Boone, Buchanan (CMG), Cole and Gentry (EHF) counties.

160. *Geocoris uliginosus* (Say).—Adults are to be found commonly the year around, hibernating under mullein leaves and in grass clumps. In summer they are found under objects on the ground or are swept from weedy fields. Nymphs have been found hiding in the same places as the adults and seem to be numerous until late November, indicating that they too, might hibernate. Uhler (1876) and VanDuzee (1917) both record it for the state. Atchison, Boone, Camden, Cass, Crawford, Dallas, Daviess, Dent (EHF), Harrison,

Howell, Lafayette, McDonald (EHF), Mississippi, Oregon, Pulaski, St. Louis, Shannon, Stone (EHF) and Wayne counties.

161. *Geocoris frisoni* Barb.—This species, which is known from Texas, Indiana and Illinois, might occur in Missouri.

162. *Hypogeocoris piceus* (Say).—This species is represented in available collections by very few specimens. One each was taken from under the leaves of *Rumex* and *Plantago*. Several adults and nymphs were found running on the ground among grasses and sedges in a low, moist field. April, June and August are the months recorded on the specimens at hand. The nymphs were found in June. Boone, Pike (WSC) and St. Louis counties.

163. *Phlegyas abbreviatus* (Uhl.).—A common species that should occur throughout the state. It was described in part from Missouri under the generic name *Helonotus* (1876). VanDuzee (1917) records it for the state under its present name. Adults have been collected from April 6 until September 24, but they should be found the year around. Nymphs have been observed from early June until late September. Both adults and nymphs have been swept from weedy fields and open woods. Adair (EHF), Atchison, Audrain, Barry, Bollinger, Boone, Cape Girardeau (CWW), Carter, Cass, Clark (EHF), Cole, Crawford, Dallas, Daviess (EHF), Dent, Franklin, Harrison, Holt, Iron, Jasper, Jefferson, Johnson, Lafayette, Lawrence (WWS), Lewis, Lincoln, Livingston, McDonald, Macon, Maries, Mercer, Miller, Mississippi, Morgan (EHF), Nodaway, Oregon, Perry, Phelps (EHF), Pike, Randolph, Ste. Genevieve, St. Louis, Saline, Scotland (EHF), Schuyler, Scott, Shannon (EHF), Taney, Vernon, Wayne and Webster counties.

164. *Oedancala dorsalis* (Say).—A common species that should be found throughout the state. Adults and nymphs have been swept from weedy fields and open woods. Adult records are for the period from April 13 to August 12. Nymphs were collected between June 25 and July 20. Atchison, Barry, Buchanan, Butler, Carter, Christian (WWS), Clark, Dallas, Dunklin, Franklin, Iron, Jasper, Lafayette, Lawrence (WWS), Livingston, Macon, Miller (EHF), Newton, Nodaway, Phelps, St. Louis, Saline, Schuyler, Stoddard (EHF), Vernon and Webster counties.

165. *Crophius disconotus* (Say).—Originally described from "Missouri" in 1832 as *Lygaeus disconotus*, this species has subsequently been listed for the state by VanDuzee (1917) and Blatchley (1926), always without definite locality. Although no Missouri specimens were available, its occurrence in the state is likely as it is said to range throughout the "eastern part of the U. S."

166. *Myodocha serripes* (Oliv.).—Adults of this very common species, which should occur throughout the state, are to be found the year around. They hibernate under rocks and logs, often in large colonies, and in summer are to be found in fields and at lights. Nymphs, which have been taken between June 18 and October 27, are most often seen under rocks and logs but sometimes they can be found running on the ground among grass and weed stems in fields. It is recorded for the state by Uhler (1876) and VanDuzee

(1917). Atchison, Barry, Bates, Boone, Buchanan, Butler (EHF), Cass, Chariton, Dunklin, Crawford, Gentry (EHF), Henry, Howell, Howard, Iron, Johnson, Lafayette, Lawrence, Lewis, Linn, Marion, Mercer, Miller, Mississippi, Montgomery, New Madrid, Oregon (EHF), Osage, Pemiscot (EHF), Perry, Pettis (WRE), Phelps, Pike (WSC), Ste. Genevieve, St. Louis, Shannon, Stoddard, Stone (EHF), Taney and Vernon (EHF) counties.

167. *Heraeus plebejus* Stal.—The few specimens in local collections have been taken in miscellaneous sweepings during May, July and September. Boone, McDonald, Pemiscot, Pettis (WRE) and St. Louis counties.

168. *Ligyrocoris obscurus* Barb.—This species is listed for Illinois and Kansas and so undoubtedly will be found in Missouri.

169. *Ligyrocoris diffusus* (Uhl.).—All specimens have been taken in sweepings in weedy fields and open woods between July 1 and October 15. Boone, Clark (EHF), Daviess, Johnson, Lafayette, Macon, Mercer, St. Louis and Scotland counties.

170. *Ligyrocoris sylvestris* (Linn.).—This so-called northern species has been taken as far south as the southern border of the state where it occurs along with many of the more truly southern species. It should, therefore, occur throughout the state. The dates of capture range from May 24 to October 19. Carter, Crawford, Franklin, McDonald and Oregon counties.

171. *Orthaea longulus* (Dall.).—This southern species enters Missouri only in the southeastern lowland section. There it is fairly common, numerous adults and nymphs being taken on August 11-13 and again on October 7 and 8 in Dunklin, Mississippi and Pemiscot counties.

172. *Orthaea basalis* (Dall.).—A common species that should occur throughout the state. Adults are to be found the year around, hibernating under rocks, logs and in grass clumps and occurring in weedy fields and coming to lights during the summer. Uhler (1876), under the name *Pamera basalis*, lists a specimen taken in "Missouri" by C. V. Riley. Several adults and nymphs were found crawling among debris on the ground between weeds growing at the edge of a corn field. All available nymphal records fall in the months of August and September. Atchison, Barry, Boone, Butler, Callaway (WRE), Carter, Cass, Cole, Dade, Daviess, Dent (EHF), Jackson, Jefferson (EHF), Lafayette, McDonald, Pemiscot, Pike (WSC), Pulaski, Ste. Genevieve, St. Louis, Schuyler, Stone, Taney and Texas counties.

173. *Orthaea bilobata* (Say).—One specimen of this southern species was taken at lights in Columbia (Boone Co.) on September 15. Two days later several more were found at lights in Jefferson City (Cole Co.).

174. *Orthaea servillei* (Guer.).—Another species that is found not uncommonly within the boundaries of this state. All specimens have been collected by sweeping shrubs and weeds near water between the dates of April 17 and October 8. Butler, Dunklin, New Madrid, St. Charles, St. Louis and Shannon counties.

175. *Zeridoneus costalis* (VanD.).—A single male collected at Roach (Camden Co.) on June 21 was tentatively placed under this name by Mr. H. G. Barber with the remarks, "Presents certain differences and might be new but without more specimens for comparison cannot be certain of this. It is a variable species." It differs most conspicuously from typical *costalis* in color, the pale stripes are missing from the hind lobe of the pronotum and the legs are not marked with black.

176. *Perigenes similis* Barb.—This species, which was described from a lone female from Texas, is much more common in Missouri than is *constrictus* (Say) to which it is closely allied. Although unmentioned in the original description the antennal characters here used in the key are practically the only ones that can be put into words effectively. It is distinct from Say's species but the many "more" or "less" characters that separate the two are too difficult to use unless both species are at hand. In the females the antennae and legs are marked with fuscous as in *constrictus* but in the males the basal antennal segment and legs are without fuscous marking of that species. Adults have been taken between June 2 and October 7 by sweeping in weedy fields and collecting at lights. Boone, Jefferson (EPM), Pemiscot, St. Louis and Wayne counties.

177. *Perigenes constrictus* (Say).—In Missouri this uncommon species has been swept from weedy fields during the period from June 3 to September 20. On one occasion adults and nymphs were found running together on the ground among weeds in a low marshy field. The legs of both sexes of this species are marked with fuscous. Boone, Dunklin, Jefferson, Macon and St. Louis counties.

178. *Ptochiomera nodosa* Say.—A common species that should occur throughout the state. It has been found the year around, being collected from under logs, boards, rocks, at lights and in grass clumps. Nymphs have been found in company with adults from August 11 until October 3. Uhler (1876), VanDuzee (1917) and Barber (1928) list Missouri among their localities for this species. Boone, Camden, Chariton, Dunklin, Franklin (EHF), Linn, Mercer, Perry, Pettis (WRE), Pike (WSC), Polk, Pulaski, Ste. Genevieve and St. Louis counties.

179. *Ptochiomera* (?) *puberula* Stal.—Mr. H. G. Barber identified my material of this species with the remark, "Certainly the genus will have to be changed." It definitely is not congeneric with *nodosa* Say which is the type of *Ptochiomera*. Two of the three specimens at hand were collected from under rocks, the third was found in a clump of *Andropogon*. Barton Co., January 3 (WSC); Columbia (Boone Co.), February 26; and Devil's Elbow (Pulaski Co.), April 14.

180. *Sisamnes clavigera* Uhl.—A scarce species that is found under rocks, logs, boards and mullein leaves. Adult records are at hand from September 18 through April 22 and again for July 14. A single fully grown nymph was found under a rock on September 24. On the next day it transformed into an

adult. It is listed for "Mo." by Barber (1928). Boone, Camden, McDonald, Pettis (WRE), St. Louis and Stone counties.

181. *Sisamnes antennata* VanD.—Although this species was originally described and subsequently listed only for Florida, a single specimen was found in a clump of *Andropogon* near Noel (McDonald Co.) on June 27. Mr. H. G. Barber, who identified the specimen for me, writes to me that this species might prove to be the same as *S. contractus* which Distant described from Guatemala.

182. *Cnemodus mavortius* (Say).—Described (1832) in part from "Missouri" under the generic name *Astemma,* this species is to be found uncommonly under rocks and logs. Adults have been found during every month of the year. Several nymphs were taken from under a log on September 15. The variety *inflatus* of VanDuzee is apparently superfluous. It is separated by the inflated front lobe of the pronotum and the short beak which reaches only to front coxae. In the material at hand this condition prevails only in some of the brachypterous specimens, never in the fully-winged individuals. Among the brachypterous specimens, though, intermediate forms are prevalent. In some the front lobe of the pronotum is wider than the hind one and the beak distinctly surpasses front coxae but does not reach the intermediate ones. In others the front lobe is equal in width to the hind one and the beak either slightly surpasses front coxae or reaches all the way to the middle pair. In the others the front lobe is narrower than the hind one and the beak extends beyond the front coxae but does not reach mid coxae. In the macropterous specimens the hind lobe of the pronotum is wider than the front one and the beak varies in length between the front and middle coxae. The species is listed for the state by Uhler (1876), VanDuzee (1917) and Blatchley (1926). In addition Blatchley lists a specimen under the varietal name from "Bigelow, Mo., Aug. 28 (Barber)." Boone, Cole, Crawford, Franklin, Iron, Saline and Taney counties.

183. *Pseudocnemodus canadensis* (Prov.).—This species has been found as far west as Nebraska and Kansas and so will probably be found in Missouri.

184. *Ozophora picturata* Uhl.—A scarce species, adults of which have been collected under logs and rocks from May 11 to August 3. Nymphs were found under a log with adults on June 21. Boone, Butler (CWW), Iron, Oregon (EHF), St. Louis and Webster counties.

185. *Tempyra biguttata* Stal.—A single specimen of this rare species was found dead in a hole in one of the shelf fungi, Polyporus, at Columbia (Boone Co.) on February 29.

186. *Peritrechus fraternus* Uhl.—A not uncommon species that occurs under rocks, logs and in grass clumps and occasionally comes in some number to lights. It has been found during every month of the year as imago. Boone, Dunklin, Moniteau, Oregon (EHF), Pettis, St. Louis and Schuyler counties.

187. *Antillocoris pilosulus* (Stal).—Except for one specimen that was

found in a grass clump, all available Missouri material was collected at lights. April 16 and September 23 represent extremes of the period during which adults have been taken. Boone, Butler, Cole, McDonald and Stoddard counties.

188. *Antillocoris pallidus* (Uhl.).—Because this has the same recorded distribution as the preceding, as far west and southwest as Indiana and Texas, it is probable that it occurs in Missouri.

189. *Cligenes delineata* Dist.—Mr. H. G. Barber named my two specimens, one broken, as this "with some question." In the letter he further says, "The author's description (as usual) is so incomplete that it is impossible to be certain of its identity. I have seen the same thing from Idaho, Oregon and California." He also records it, in literature, from Texas. The two Missouri specimens were taken from a clump of *Andropogon* on a sparsely wooded, rocky hillside near Noel (McDonald Co.) on June 27.

190. *Malezonotus sodalicius* (Uhl.).—Numerous specimens were found hibernating in clumps of *Andropogon* on a prairie near Windsor on March 1. One other was taken at Marshall on May 19 (EHF).

191. *Sphragisticus nebulosus* (Fall.).—A scarce species which has been taken at lights. One specimen in the University of Missouri collection bears the label "Columbia, Mo., June 19, 1907." The others were taken between the dates of May 6 and September 18 in Boone, Cole and Lafayette counties.

192. *Aphanus umbrosus* (Dist.).—An uncommon species in this state. Although adults have been collected only from September 7 through April 14, they should be found the year around, hibernating in grass clumps or under rocks, logs or mullein leaves. Boone (WSC), Dade, Johnson, Moniteau, Pettis, Pike (WSC), Pulaski and St. Louis counties.

193. *Aphanus illuminatus* (Dist.). — Two Missouri specimens of this scarce species are at hand: one from under mullein leaves near Vichy (Maries Co.) on March 9 (EHF) and the other from under a board near Columbia (Boone Co.) on April 6.

194. *Emblethis vicarius* Horv.—All but one of the available Missouri specimens were collected from lights: Columbia (Boone Co.), February 26, September 18 and October 9; Jefferson City (Cole Co.), October 24. The other was found under a board near Columbia on April 6.

195. *Drymus unus* (Say).—This species is said to occur from New England west to Colorado and southwest to North Carolina and Texas and so probably will be found in Missouri.

196. *Drymus crassus* VanD.—Southern Illinois is apparently the westernmost known point of occurrence of this species but there is a good possibility that it might be found in Missouri.

197. *Eremocoris ferus* (Say).—An uncommon species that should occur throughout the state the year around. Specimens at hand were collected during

June and July from weedy fields and at lights. Barber (1923) lists it for the state. Boone, Cole and St. Louis counties.

198. *Eremocoris setosus* Blatch.—This species is widely distributed in the east and occurs as far west as Indiana and as far south as Florida so it might be found in Missouri.

199. *Cryphula parallelogramma* Stal.—All the Missouri specimens of this species that I have seen were collected under rocks and other debris in woods between the dates of September 16 and April 16. It will quite probably also be found during the summer months. Boone, Cass, Crawford (EHF), McDonald (EHF) and St. Louis counties.

PYRRHOCORIDAE

200. *Euryophthalmus succinctus* (Linn.). — An uncommon species that appears to be restricted to the southern two-thirds of the state: that is, to the Ozark and Ozark Border Regions. Specimens have been observed feeding and mating on strawberry plants in June. Except for an occasional one that has been found wandering over the foliage of oak trees, most of the rest of the adults have been collected from under rocks, logs and leaves on the floor of woods. Nymphs have swept commonly from various species of oaks, several different sumachs and from the wild blue-berry, *Vaccinum*. Adult records extend from April 13 to September 7. Nymphs have been taken during the period between June 18 and August 15. Butler, Carter, Crawford, Dallas, Dent, Dunklin, Franklin (WRE), Iron, Oregon (EHF), Phelps, Pulaski and Shannon counties.

201. *Arhaphe carolina* (H-S).—A scarce species, all specimens of which have been taken while they ran erratically among the fallen leaves on the floor of wooded hills in the Ozark Region of the state. Adults have been collected during May, June and September in Barry, Crawford, Franklin (WRE), Oregon and Shannon (EHF) counties.

202. *Arhaphe breviata* Barb.—There is a possibility that this species, which was described from several widely separated stations in Kansas, might include part of Missouri in its range. Until more is known about it, we had better include it so that it may be recognized if found.

203. *Dysdercus suturellus* (H-S). — This species, which is commonly known as the "cotton-stainer" or "red bug," is not known to occur in the state at present. Conscientious collecting in the cotton district in the southeastern lowland section of the state failed to yield any specimens. The several insects that have been submitted to me as this species all proved to be the Lygaeid *Lygaeus bicrucis* Say.

PIESMIDAE

204. *Piesma cinerea* (Say).—A very common species that breeds on pigweed, *Amaranthus*, here as elsewhere. Adults are frequently found on flowers and foliage of various other kinds of plants. Imagoes, which are to be found

the year around, hibernate singly or in small colonies under loose bark, in grass clumps and under logs and other debris. One pair of specimens from Florence, September 16 (EHF), agrees well with the description of McAtee's variety *inornata*. This variety is greenish and lacks all dark markings. Atchison, Bates, Boone, Cass, Chariton, Dade, Dunklin, Franklin, Henry, Holt, Jasper, Lewis, McDonald, Miller (EHF), Pemiscot, Pike (WSC), Saline, St. Louis and Schuyler counties.

TINGIDIDAE*

205. *Corythucha cydoniae* (Fitch).—This uncommon species is probably of state-wide distribution. Adults have been swept from *Crataegus* and both adults and nymphs have been found on Quince in June. Definite adult records are from April 23 to July 2 and again on September 21. Bollinger (CWW), Boone, Clark, Cole, Maries, Mercer (EHF), Oregon, Pike, Schuyler and Washington counties.

206. *Corythucha ciliata* (Say).—Adult and nymphs are common on sycamore, whence the common name of "sycamore lace bug." On one occasion numerous adults were swept from cypress. Adults occur the year around, hibernating singly or in small groups under logs, under bark of various species of trees and in grass clumps. Nymphs have been observed from May 25 to September 11. Barry, Boone, Clark, Crawford, Dade, Dunklin, Henry, Jefferson, Lafayette, McDonald, Maries, Miller, Pemiscot, Perry, St. Louis, Saline, Shannon (EHF), and Vernon counties.

207. *Corythucha pallida* O. & D.—One specimen from St. Louis on June 25 and another from Columbia (Boone Co.) on July 4 represent the only Missouri material of this species seen in preparation of this work.

208. *Corythucha mollicula* O. & D.—Represented in available collections by a single Missouri specimen collected at Tyler (Pemiscot Co.) on October 7.

209. *Corythucha marmorata* (Say).—This very common species is found breeding most abundantly on *Helianthus* and *Solidago*. A common name, "chrysanthemum lace bug," is derived from the occasional occurrence on and damage to cultivated 'mums. Adults are to be found the year around, hibernating in grass clumps and under leaves and other debris on the ground. Barry, Boone, Caldwell, Camden, Crawford, Dunklin (EHF), Franklin, Howell (EHF), Jasper, Johnson, Lafayette, Lewis, McDonald, Macon, Maries, Miller, Mississippi, Montgomery, Morgan, Oregon, Pemiscot, Phelps, Scotland (EHF), St. Louis, Shannon, Stoddard, Taney and Vernon (WRE) counties.

210. *Corythucha arcuata* (Say).—Some of the specimens at hand are obviously of the nominal or typical form, having the apical cross-bar strongly indicated, while some of the others lack entirely that marking and so undoubt-

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* Van Duzee (1917), in his "Catalogue" lists *Dictyonota tricornis americana* Parsh. for "Mo." This is a typographical error for "Me.", the state from which it was described.

edly belong to the variety *mali* of Gibson, but all the intergrading forms are so completely represented that I find it impossible to draw a dividing line. Therefore, all records are listed under the specific name. Adults have been found throughout the year, hibernating in grass clumps and under bark and breeding on white oaks. Nymphs have been observed in June and September. Barry, Boone, Camden, Dade, Harrison, Jefferson, McDonald, Maries, Perry, Platte, St. Louis, Saline, Stone (EHF) and Taney counties.

211. *Corythucha pruni* O. & D.—The host plant of this species, the wild cherry, *Prunus serotina* L., is known to occur throughout Missouri so we will probably find the lace bug associated with it.

212.—*Corythucha ulmi* O. & D. — A single specimen was swept from shrubby growth along a trail near Van Buren (Carter Co.) on June 16, while four more were taken from elms near Marshall (Saline Co.) on April 20 and May 5. It should occur on elm throughout the state.

213. *Corythucha aesculi* O. & D.—Adults have been found commonly on buck-eye, *Aesculus glabra* Willd., between March 26 and June 25. Barry, Boone, Lewis, Perry and St. Louis counties.

214. *Corythucha pergandei* Heid.—This species has been recorded from as far west as Kansas so there are good probabilities of its occurring in Missouri.

215.—*Corythucha juglandis* (Fitch).—Another species that has been listed for Kansas and eastward but for which I have seen no Missouri specimens. Its food is said to include walnut, pecan, butternut and linden.

216. *Corythucha contracta* O. & D.—This species is reported as being found on walnut, pecan and butternut as far west as Illinois. Since all these trees occur in Missouri there seems to be little reason to doubt that this insect will be found in at least the eastern part of the state.

217. *Stephanitis pyrioides* Scott.—In November numerous specimens of this, the "azalea lace bug" were found on azaleas that had just been brought into a greenhouse for the winter. Adults and nymphs were feeding on the lower surfaces of the leaves and causing the characteristic whitening of the upper surfaces. Although known locally only from St. Louis, it probably has a wider distribution in the state.

218. *Gargaphia tiliae* (Walsh).—The only available Missouri specimens were taken from linden, *Tilia americana*, between the dates of May 5 and September 16. Barry, Boone (WRE), Saline and Schuyler counties.

219. *Gargaphia amorphae* (Walsh).—Specimens have been collected from *Amorpha fruiticosa* L. and other members of the genus between May 12 and October 8. Boone (WSC), Dunklin, Lewis (EHF), and Stone counties.

220. *Gargaphia solani* Heid.—This species was described (1914) in part from Missouri material labelled "Kirkwood, Mo., August 10 (Riley and Per-

gande) on *Solanum carolinense* and *Solanum elaeagnifolium*." It breeds commonly on *S. carolinense* L. and is often found breeding on and causing severe injury to egg-plants in gardens. Adults have been collected during the entire year, usually hibernating in grass clumps but occasionally found under bark or mullein leaves. Available nymphal records are for June and July. VanDuzee (1917), Gibson (1919) and Blatchley (1926) also list it for the state. Barry, Boone, Cape Girardeau (CWW), Cass, Chariton, Cole, Crawford, Dallas, Daviess, Dent (EHF), Dunklin, Franklin, Gentry, Harrison, Holt, Howell, Iron, Jackson, Jefferson, Johnson, Lafayette, Livingston (EHF), McDonald, Macon, Mercer (EHF), Miller, Moniteau, Morgan (EHF), Pemiscot (EHF), Perry, Pettis (WRE), Ste. Genevieve, St. Louis, Saline, Scott, Shannon (EHF) and Stoddard counties.

221. *Gargaphia angulata* Heid. — An uncommon species in this state. Records indicate adults as of April 29 and then for a continuous period from July 21 until September 24. It is listed for the state by Gibson (1919). Crawford, Lawrence (WWS), McDonald, Oregon, Ste. Genevieve, St. Louis, Taney and Stone counties.

222. *Leptopharsa clitoriae* (Heid.).—It has been swept commonly from *Clitoria mariana* L. in oak woods between August 7 and September 23. Crawford, Howell, Perry (EHF) and Phelps counties.

223. *Leptopharsa oblonga* (Say).—This species was originally described (1825) from "Missouri" as *Tingis oblonga*. VanDuzee (1917) lists it for the state under the genus *Leptostyla*, a preoccupied name. Although I have seen no local specimens it should be found throughout the state.

224. *Leptopharsa heidemanni* (O. & D.).—A pair was swept from a roadside field at Vichy (Maries Co.) on June 17.

225. *Acalypta lillianis* Bueno.—Known to occur as far south and west as southern Illinois, this species will probably be found in Missouri.

226. *Physatocheila plexa* (Say).—Having been recorded as far south and east as Virginia, this species will undoubtedly be found in Missouri.

227. *Physatocheila major* O. & D.—With the same recorded range as *P. plexa*, this species should also occur in Missouri.

228. *Physatocheila variegata* Parsh.—Two females were taken from the smaller branches of a willow along a stream in Ste. Genevieve County on May 11.

229. *Teleonemia nigrina* Champ.—Adults and nymphs have been found feeding on *Plantago aristata* Michx. and *Verbena* sp. in an open woods. Available dates, which extend from May 13 to November 16 indicate that this species occurs as adults the year around. Nymphal records are for the months of July and August. Boone (WSC), Cass (EHF), Shannon and Wayne counties.

230. *Teleonemia cylindricornis* Champ.—This species was described from

Central America and has since been listed as far north and east as Illinois and so should be found in Missouri.

231. *Melanorhopala clavata* Stal.—A macropterous and two brachypterous specimens are at hand. The former was swept from a weedy, road-side ditch. The others were swept from weedy fields near St. Peters (St. Charles Co.) on May 29 and Atlanta (Macon Co.) on June 8 (EHF).

232. *Hesperotingis antennata* Parsh.—A single specimen of the nominal form is at hand from Greer (Oregon Co.), August 2. It was swept from an overgrown field that had formerly been under cultivation. One other Missouri specimen from Columbia (Boone Co.), October 13 (WSC), was tentatively identified for me by Dr. Drake as the variety *borealis*. He points out that it differs from his specimen of this variety in having antennals I and III of different lengths and the lateral carinae of the pronotum curved anteriorly. He further states that there is quite some variation in the members of this genus of scarce Tingids and consequently hesitates to make any other placement of this lone individual.

233. *Alevotingis brevicornis* O. & D. — Known heretofore from only a single specimen, the type, which was taken in Iowa, this species is now represented by a Missouri specimen which was netted while it flew through an open woods near Lancaster (Schuyler Co.) on June 23. Dr. C. J. Drake compared my specimen with the type, which is in his collection, and said that the two matched very closely.

234. *Atheas mimeticus* Heid. — This species has been commonly found breeding on *Petalosteum purpureum* (Vent.) Rydb. during August and September. Carter, Howell (EHF), McDonald and Oregon counties.

235. *Atheas austroriparius* Heid.—Two specimens were collected at Greer (Oregon Co.) on August 2.

236. *Atheas annulatus* O. & D.—This species was described from Marion County, Arkansas, which is adjacent to Ozark and Taney counties in Missouri, and so should be found in Missouri.

237. *Leptoypha costata* Parsh. — Because this species has been listed for Illinois, Arkansas and Colorado, it should undoubtedly be found here.

238. *Leptoypha elliptica* McA.—Adults and nymphs have been collected during May in Dunklin and St. Charles counties.

239. *Leptoypha mutica* (Say).—Specimens have been swept from white ash, *Fraxinus americana* L. during August and September in Barry, Jefferson, Lewis and McDonald counties.

ENICOCEPHALIDAE

240. *Systelloderes terrens* Drk. & Harr.—This species probably occurs in Missouri as it was described from Burlington, Iowa, which is within forty miles of this state's borders.

241. *Systelloderes biceps* (Say). — Under a synonym, *Henicocephalus culicis* (Uhl.), Johannson (1909), writing about some specimens he had for study, said, "Another, possibly of the same species, at Columbia, Missouri and now in the University of Missouri Collection." There are at present no Missouri Enicocephalids in the University Collection. In fact, I have seen no specimens of this group from the state. However, its known range indicates that it will probably be found throughout.

PHYMATIDAE

242. *Phymata vicina* Handl.—A single specimen of this species was found among the inflorescence of *Eupatorium* sp. in Adair County on June 23. It should occur throughout the state.

243. *Phymata fasciata georgiensis* Melin.—The nominal form of this is said to be restricted in distribution to Mexico. Our form occurs commonly and should be found throughout the state. Adults have been collected between April 13 and September 4. It is recorded for the state by VanDuzee (1917) under the name *Phymata erosa fasciata*. Evans (1931) lists it under the present name and, on the basis of specimens studied, records it from "Missouri." Barry, Boone, Buchanan, Carter, Cole, Lawrence, Montgomery (EHF), Osage (EHF), Phelps, Ste. Genevieve, St. Louis, Saline and Schuyler counties.

244. *Phymata pennsylvanica pennsylvanica* Handl.—A scarce form. Only three stations, and those all in the southeastern quarter of the state, have yielded specimens. They were Fisk (Butler Co.), July 14; Ironton (Iron Co.), July 23; and Holcomb (Dunklin Co.), August 23. VanDuzee (1917) lists this form for Missouri as *Phymata erosa wolffii* Stal.

244a. *Phymata pennsylvanica americana* Melin.—This form is much more common than the nominal one, in fact, it is the commonest Phymatid in the state. Adults have been collected from July 12 to October 22. On the basis of specimen material Evans (1931) records this form for Missouri. Boone, Carter, Crawford, Dunklin, Harrison, Holt, Iron, Lawrence (WWS), Lewis, Linn, Macon, Nodaway, Oregon, Phelps, Pulaski, St. Louis, Shannon, Taney and Wayne counties.

245. *Macrocephalus prehensilis* (Fab.).—This species has been listed for Kentucky, Arkansas, Oklahoma and Kansas and so therefore will probably be found in Missouri.

PLOIARIIDAE

246. *Empicoris tuberculatus* (Banks).—This widely spread species, which is treated as *E. errabundus* (Say) by McAtee and Malloch, ranges from New England southwest to Georgia and Texas and west to Iowa and Kansas and so is likely to be found in Missouri.

247. *Empicoris rubromaculatus* (Blackburn).—Another probable species for Missouri, this one has been listed as occurring in California, Indiana, Mississippi, Florida and Virginia.

248. *Emesaya brevipennis* (Say). — This species, which should occur throughout most of the state, is represented by only two locality-date records. One specimen was taken from a tree trunk near St. Louis on March 8. On July 20, Mr. W. S. Craig took numerous specimens from an old shed near New Hartford (Pike Co.). McAtee and Malloch (1925) list it for the state.

249. *Metapterus annulipes* (Stal).—Two Missouri specimens are at hand, both from under rocks. One was from Clark County, September 16 and the other from McDonald County, November 3.

250. *Metapterus fraternus* (Say).—Specimens have been collected from under rocks and on the ground among weeds and grasses in fields. Although Missouri records show specimens from August 23 to November 28, they should be found throughout the year. Boone, Cass, Clark and Perry counties.

251. *Metapterus uhleri* (Banks). — A common species that should be found throughout the state. It has been taken from beneath boards and rocks, either in or bordering woods. Adults have been collected during March, April, August and September. Several partially grown nymphs were taken from under a rock with a single adult on December 8. Cass, Jefferson, McDonald, Osage and Pulaski counties.

REDUVIIDAE*

All our members of this family are predaceous and the majority of them may be considered beneficial because their chief source of food is found in the myriads of plant feeding insects. If some of the larger forms are handled carelessly they can pierce the finger or hand and cause a severe pain which is often followed by several days of numbness.

252. *Oncerotrachelus acuminatus* Stal.—A not uncommon little species probably of state-wide occurrence, that is to be found under cover in moist places or at lights. Adults have been found the year around. Boone, Cole, Mississippi and Pike (WSC) counties.

253. *Pnirontis modesta* Banks.—The only Missouri specimen seen is in the collection of the University of Missouri and bears the data, "Columbia, Mo., July 17, 1930."

254. *Pygolampsis sericea* Stal.—This species has been reported from Illinois to Texas and so should be found in Missouri.

255. *Pygolampsis pectoralis* (Say). — The available Missouri specimens have been taken at lights in September and early October. Boone, Buchanan and Pemiscot counties.

256. *Stenopoda cinerea* Lap.—An uncommon species in this state. With the exception of one brachypterous female, all adults seen were macropterous.

* A single specimen of the Central American species, *Castolus plagiaticollis* Stal, was taken at New Hartford on February 15 (WSC) from a stalk of bananas. Dr. Barber, who identified it, writes that it is frequently intercepted on that fruit.

They were collected between the dates of June 18 and August 12. This species winters in the later nymphal stages, the larger nymphs being found from late October until middle June. Boone, Crawford, Mississippi (WSC), Oregon, Pike (WSC), Pulaski and St. Louis counties.

257. *Oncocephalus geniculatus* Stal. — Three specimens of this southern species are at hand: Cape Girardeau Co., June 15 (CWW); and two in Pettis Co., June 5 and 9 (WRE).

258. *Oncocephalus apiculatus* Reut.—No Missouri specimens of this species were seen during this study. It was, however, originally described (1882) from the state and has subsequently been reported for both Illinois and Kansas and so should be found here. All other Missouri records are apparently based on the original description: Fracker (1913), VanDuzee (1917), Blatchley (1926) and Readio (1927).

259. *Narvesus carolinensis* Stal.—Adults of this uncommon species have been found under rocks and at lights between June 11 and August 9. It is listed for Missouri by Uhler (1876), Fracker (1913), VanDuzee (1917), Blatchley (1926) and Readio (1927). Boone, Newton and St. Louis counties.

260. *Reduvius personatus* (Linn.).—This species, which is known by the common name of "kissing bug," appears to be quite scarce in Missouri. I have seen only six specimens from the state. They were taken between June 5 and August 28 in Miller, St. Louis and Scott counties.

261. *Triatoma sanguisuga* (Lec.).—Adults of this rather common species have been taken during every month of the year. Nymphal records are from December 11 to April 20, but judging from the variety of sizes of the immatures found in this period, it seems safe to assume that nymphs will be found nearly, if not quite the year around. Adult and nymphs are both taken commonly from under loose bark. Bates, Boone, Crawford, Maries, Ste. Genevieve, St. Louis and Saline counties.

262. *Triatoma heidemanni* Neiva.—A single, nearly fully grown nymph of what is apparently this species is at hand from Newburg (Phelps Co.), March 30. This specimen differs from undoubted nymphs of *sanguisuga* by some of the same characters that are used to separate the adults: namely—the beak is pilose, and has the second segment only a third longer than the first; also the tubercles at the apical angles of the pronotum are blunt.

263. *Triatoma rubrofasciata* (DeG.).—I have seen no specimens of this species, but Walker (1873) records it from the state. Usinger (1939) seems to think that there is no reason for doubting the validity of this record so we will have to keep this name on our lists, for a while, at least.

264. *Melanolestes picipes* (H-S).—This is a common species, adults of which are to be found the year around. Except for some of the fully-winged individuals that come to lights, most specimens are collected from under logs, rocks and other cover. In the material inspected, all of the males and about one-fourth of the females were fully-winged, the rest of the females had abbre-

viated wings that did not exceed the second abdominal tergite. Bates, Boone, Buchanan, Butler, Cass, Cole, Crawford, Henry, Jefferson, Lewis, Miller, Polk, Ste. Genevieve, St. Francois, St. Louis, Saline and Vernon (WRE) counties.

265. *Melanolestes abdominalis* (H-S).—This species is not quite as common as *picipes*, with which the females appear to intergrade, but is found in the same type of habitat. All of the adult males seen were macropterous and all the females were brachypterous. Adults were found throughout the year, nymphs in July and August. Barry, Boone, Buchanan, Butler, Crawford, Harrison, Iron, Polk, Pulaski (EHF), St. Louis and Washington counties.

266. *Rasahus hamatus* (Fab.). — The nymphs of this species have been collected commonly from under rocks and logs throughout most of the Ozark Region of the state. Even though nymphs are very common, adults are relatively scarce. All the available adults were found during June. Some of them were taken from under the very rocks and logs where nymphs were observed to be abundant earlier in the season. Records of immatures extend from September 15 until June 2. Barry, Iron, Jasper, Montgomery, Newton, Oregon, St. Louis, Shannon (EHF), Stone and Taney counties.

267. *Sirthena carinata* (Fab.).—A single adult specimen in the University of Missouri collection bears the label, "Columbia, Mo., May 3, 1905." The only other Missouri specimen seen was collected at Barnhart on June 10, 1935, by Dr. E. P. Meiners.

268. *Rhiginia cruciata* (Say).—Originally described from "Indiana and Missouri" (1832) as a member of the genus *Petalocheirus*, this species is represented in available collections by two locality-date records. A single specimen was taken at Creve Coeur (St. Louis Co.) on October 12 (EPM). One live and several dead individuals were found under loose bark on fallen trees on February 2 at Qulin (Butler Co.) which is in the lowlands of the southeastern region of the state.

269. *Hammacerus purcis* (Dru.).—In Missouri this not uncommon species seems to be confined to the Ozark Region south of the Missouri River. Both adults and nymphs have been found under loose bark of standing or fallen trees. Records of imagoes extend from September 24 to March 3. Small nymphs have been collected during November and December. Carter, Crawford, Greene, Oregon, Osage, Ozark, St. Francois (EHF), St. Louis, Shannon and Wayne counties.

270. *Apiomerus crassipes* (Fab.).—An uncommon species that should be found throughout the state. It is usually taken by sweeping foliage and flowers of various kinds of plants in open fields or woods. Adults have been collected from June 1 until August 10. It passes the winter in the nymphal stage, several having been taken during September, November, December, March and April. Barry, Bollinger, Boone, Buchanan (CMG), Carter (EPM), Crawford, Iron, McDonald, Macon, Miller (WRE), Phelps, Pike (WSC), St. Louis and Vernon counties.

271. *Apiomerus spissipes* (Say).—A single specimen was taken from bull nettle, *Solanum carolinense* L., in St. Louis on June 28.

272. *Zelus cervicalis* Stal.—On June 22 a lone specimen was swept from an oak woods near Cassville (Barry Co.).

273. *Zelus exsanguis* (Stal). — Winter is passed by the larger nymphs which change to adults as early as April 29. From then on until late fall, adults are frequent in weedy fields and open woods. The bodies and legs of the immatures are covered with long, sticky hairs to which dust and other small particles adhere. This debris makes the insect less conspicuous. Barry (EHF), Boone, Butler, Carter (EHF), Crawford, Dallas, Iron (EHF), Linn, McDonald, Newton, Phelps, Ste. Genevieve, Shannon (EHF), Stoddard and Webster counties.

274. *Zelus socius* Uhl. — All available Missouri specimens have been taken in the northern part of the state, where it is common in weedy fields during July. It should, however, be found throughout the state. Atchison, Buchanan, Holt and Macon counties.

275. *Zelus audax* Banks.—The few Missouri specimens seen were collected at St. Joseph (Buchanan Co.) on June 22 and St. Louis on July 5 and August 9 and 26.

276. *Rhynocoris ventralis* (Say). — Originally described (1832) from "Missouri" as *Reduvius ventralis*, this species has subsequently been listed for the state by both Uhler (1876) and Fracker (1913) as *Apiomerus ventralis* and by VanDuzee (1917) and Readio (1927) under its present name. These records are apparently all based on Say's original locality data which was given at a time when "Missouri" included much more than it does now. It has since been listed only for the northern states, in the Transition Zone, and so is probably not a member of our fauna.

277. *Pselliopus barberi* Davis.—A common species, adults of which are to be found the year around. They pass the winter singly or in various sized groups under loose bark, leaves, rocks or logs. In summer they are usually swept from foliage in woods or along woodland borders. Copulating pairs have been found in March, April and May. Nymphs have been collected during June, July and August. VanDuzee (1917) lists it for the state in his "Catalogue." In addition, Blatchley (1926) records a specimen for "Springfield, Mo., April 5 (Davis)" and Readio (1927) lists it for "Missouri." Barry, Bates, Boone, Cass, Cole, Crawford, Iron, Jasper, Jefferson, McDonald, Maries, Miller, Osage, St. Louis and Stone counties.

278. *Pselliopus cinctus* (Fab.).—This species is much less common than *barberi*, but its habits are quite similar. It is found the year around, hibernating under bark and rocks and mating in spring. As yet, no nymphs have been found. Adair, Barry, Boone, Buchanan (RIW), Cole, Clark, Crawford, Franklin, Henry, McDonald (EHF), Maries, Miller, Newton (EHF), Phelps, Pike (WSC), Pulaski, St. Louis, Shannon, Stone, Taney and Vernon (EHF) counties.

279. *Pselliopus latifasciatus* Barb.—One specimen was swept from fragrant sumach, *Rhus canadensis* L., in an open woods at Devil's Elbow (Pulaski Co.) on April 14. Another was collected at Sullivan (Franklin Co.) on May 13 (WRE).

280. *Rocconota annulicornis* (Stal).—Known from New Jersey south to Florida and southwest to Kentucky, Texas and Mexico, so it will probably be found in Missouri.

281. *Repipta taurus* (Fab.).—No Missouri records are available for this species, but since its range includes southern Illinois to Texas and Florida it probably will be found here.

282. *Atrachelus cinereus* (Fab.). — Known from "Pennsylvania west to Michigan and southwest to Florida and Texas" (Blatchley-1926) this species will probably be found to occur in Missouri.

283. *Fitchia aptera* Stal.—Adults have been found under rocks and logs on wooded hillsides during the months of March, April, July, September and November and so will probably be found throughout the year. Barry, Boone, Ozark (RER), Pulaski and Vernon counties.

284. *Fitchia spinosula* Stal.—No Missouri records are available. However, this species has a wide distribution, ranging from New York to Indiana and south and west to Florida and Texas and so may be found in this state.

285. *Arilus cristatus* (Linn.).—The common name "wheel bug" refers to the semicircular, cog-wheel-like crest on the pronotum. This species is widely distributed in the state, being especially common in the southern portion where at one time seventy-six individuals were counted at lights in front of a store in a small town. A pair of bright orange-red scent sacs near the apex of the venter are extruded at the slightest provocation. These organs seem to attract more attention among the laymen than do the wheel-shaped crest or the formidable beak. Adults have been collected between the dates of June 10 and October 10 while nymphs have been found from May 18 until July 2. The eggs, which are to be found during the winter months, are usually laid in crevices or under loose bark. Barry, Barton (RER), Boone, Buchanan (CMG), Camden, Cass, Dunklin, Greene (RER), Iron, Jasper, Jefferson, Laclede, Lafayette, Lawrence (WWS), Lewis, McDonald, Macon, Maries, Miller, Mississippi, Newton, Oregon, St. Charles, St. Louis, Taney and Vernon counties.

286. *Acholla multispinosa* (DeG.).—Although the only three available Missouri specimens are from the southeastern lowlands, this species should be found throughout the state. All were collected during August in Dunklin (EHF) and Mississippi counties.

287. *Sinea complexa* Caud.—All but one of my specimens of this scarce species were swept from *Solidago* in weedy fields. The odd individual was found hibernating in a grass clump. Of the eight specimens at hand, two are males and they are brachypterous with the hemelytra reduced to slender, elon-

gate, parallel-sided pads that are just about half as long as the pronotum. Of the six females, four are macropterous, the membrane reaching almost to the apex of the abdomen. The other two females are short-winged like the males. Coincident with the atrophy of the flight organs is a reduction in the size of the hind lobe of the pronotum. Data on the available specimens indicate adult occurrence from June 23 to December 11. Boone, Oregon, Pike (JAD), St. Louis and Wayne counties.

288. *Sinea diadema* (Fab.).—A common species throughout the state. It is found principally on foliage and flowers in weedy fields. Adults have been collected between June 1 and October 29. Immatures were found from May through October. Say's synonym (1825), *Reduvius raptorius,* was described from "Missouri." Atchison, Barry, Bates, Boone, Buchanan (CMG), Carter, Cass, Chariton, Cole, Daviess, Dunklin (EHF), Gentry, Greene (RER), Holt (EHF), Howell, Jefferson, Lewis (EHF), Linn, McDonald, Macon, Madison, Maries, Mercer, Mississippi, Montgomery, Newton (EHF), Osage, Pemiscot, Perry, Phelps, Pike, Pulaski, Ste. Genevieve, St. Louis, Saline (EHF), Schuyler, Scotland, Shannon, Stone (EHF), Taney, Texas, Wayne and Webster counties.

289. *Sinea spinipes* (H-S).—Adults of this species, which is much less common than *diadema,* are at hand for the period from May 5 to November 3. It is found under much the same conditions as is *diadema*. Barry, Bates, Cape Girardeau (CWW), Cass (EHF), Clark (EHF), Dunklin, Harrison, Lafayette, McDonald, Mississippi, Phelps, Pike (WSC), St. Louis and Stone counties.

NABIDAE

290. *Pagasa pallipes* (Stal.)—With a range known to include Utah, Kansas, Florida and Texas, this species should occur in Missouri.

291. *Pagasa fasciventris* Harr.—Recently described from Virginia, Kansas and Nebraska, this species undoubtedly will be found in Missouri. Dr. Harris says, "It occurs in blue-stem clumps."

292. *Pagasa fusca* (Stein). — Adults are not uncommon in some corn fields where they have been observed feeding on chinch bugs. They were also found under logs in woods adjacent to corn fields. All specimens were collected during May, June and October. Harris (1928) records it for Missouri. Boone, St. Charles and St. Louis counties.

293. *Nabis subcoleoptratus* Kby.—This species, which is already known to occur in Illinois, Iowa and Kansas, should be found in Missouri.

294. *Nabis sordidus* Reut.—This species is not very common in Missouri. Adults of this species have been found the year around, usually under objects in moist situations. About two-thirds of the specimens seen were brachypterous. It is recorded for the state by Harris (1928). Barry, Boone, Butler, Dunklin, Franklin, Lafayette (EHF), St. Louis, Saline and Vernon counties.

295. *Nabis annulatus* Reut.—Harris (1928) records this species for Missouri. Although I have seen no specimens, it should occur throughout the state.

296. *Nabis deceptivus* Harr.—A single male specimen was taken near Lampe (Stone Co.) on September 25 (EHF).

297. *Nabis roseipennis* Reut.—This species is common the year around, adults hibernating in grass clumps or under objects. During the active season, imagoes can be found wandering over the foliage of plants or on the ground. Some specimens have been taken at lights. Harris (1928) lists it for Missouri. Boone, Cass, Cole, Dallas, Dunklin, Franklin, Gentry, Lewis, Miller, New Madrid, Osage, Pemiscot, Phelps, St. Joseph, St. Louis, Saline and Stoddard counties.

298. *Nabis capsiformis* Germ.—But five specimens of this scarce species are at hand. They were collected between May 10 and August 13 in Cass, Howell, Mississippi and Scott counties.

299. *Nabis kalmii Reut.*—Specimens of this scarce species have been collected during May, July and September. It is recorded for the state by VanDuzee (1917), Blatchley (1926) and Harris (1928). Boone, Cass, Dallas and Stoddard counties.

300. *Nabis alternatus* Parsh. — The few available adults were collected during March, May and October at Columbia (Boone Co.) and Tyler (Pemiscot Co.).

300a. *Nabis alternatus uniformis* Harr.—In Missouri this form outnumbers the nominal one by a ratio of four to one. It has been taken commonly by sweeping weedy fields and at lights. Adult records extend from March 15 to September 17. Audrain, Bates, Boone, Buchanan (CMG), Cass, Cole, Crawford, Dunklin, Franklin, Lafayette, Lewis, Nodaway, Perry, Ste. Genevieve, St. Louis and Schuyler (EHF) counties.

301. *Nabis ferus* (Linn.).—This species is found very commonly the year around, in summer on the ground, or on foliage, or commonly at lights and in winter under rocks or logs, or in grass clumps. It is recorded for the state by Harris (1928). Atchison, Audrain, Boone, Buchanan, Butler, Camden, Cass (EHF), Chariton (EHF), Clark, Crawford, Dade, Daviess, Franklin, Howell, Iron, Jefferson, Macon (EHF), Maries (EHF), Mississippi, Nodaway, Osage, Pemiscot, Phelps, Platte, Randolph, St. Louis, Saline, Schuyler, Stoddard and Stone counties.

302. *Metatropiphorus belfragii* Reut.—The single Missouri specimen seen during this study was swept from a low, marshy, open woods near Fisk (Butler Co.) on July 14.

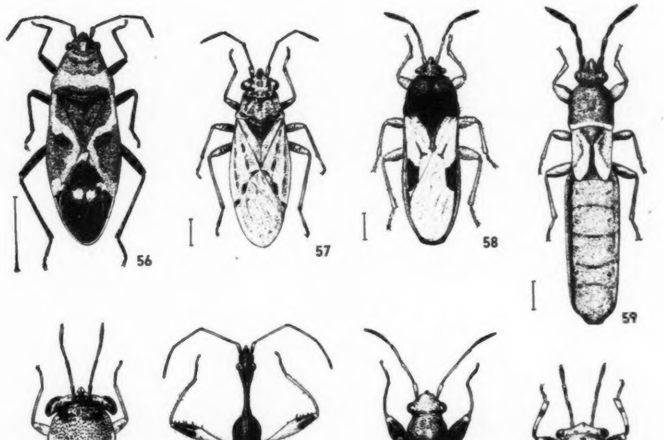

PLATE 6.—Fig. 56. *Lygaeus kalmii*; Fig. 57. *Nysius ericae*; Fig. 58. *Blissus leucopterus*; Fig. 59. *Ischnodemus missouriensis*; Fig. 60. *Geocoris punctatus*; Fig. 61. *Myodocha serripes*; Fig. 62. *Orthaea basalis*; Fig. 63. *Phlegyas abbreviatus*; Fig. 64. *Aphanus illuminatus*; Fig. 65. *Ptochiomera nodosa*; Fig. 66. *Peritrechus fraternus*; Fig. 67. *Eremocoris ferus*.

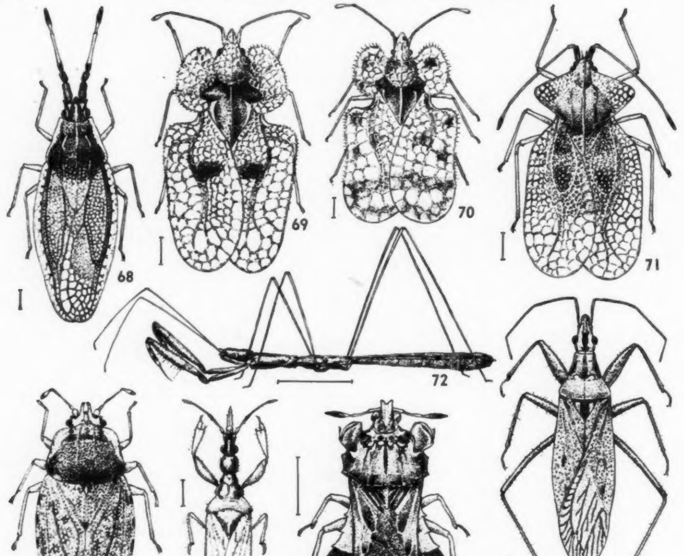

PLATE 7.—Fig. 68. *Atheas mimeticus;* Fig. 69. *Corythucha ciliata;* Fig. 70. *Corythucha marmorata;* Fig. 71. *Cargaphia solani;* Fig. 72. *Metapterus uhleri;* Fig. 73. *Piesma cinerea;* Fig. 74. *Systelloderes biceps;* Fig. 75. *Phymata fasciata georgiensis;* Fig. 76. *Nabis ferus;* Fig. 76a. *Nabis ferus*, lateral view of pronotum; Fig. 76b. *Nabis alternatus*, lateral view of pronotum; Fig. 77. *Arhaphe carolina;* Fig. 78. *Euryophthalmus succinctus;* Fig. 79. *Pagasa fusca.*

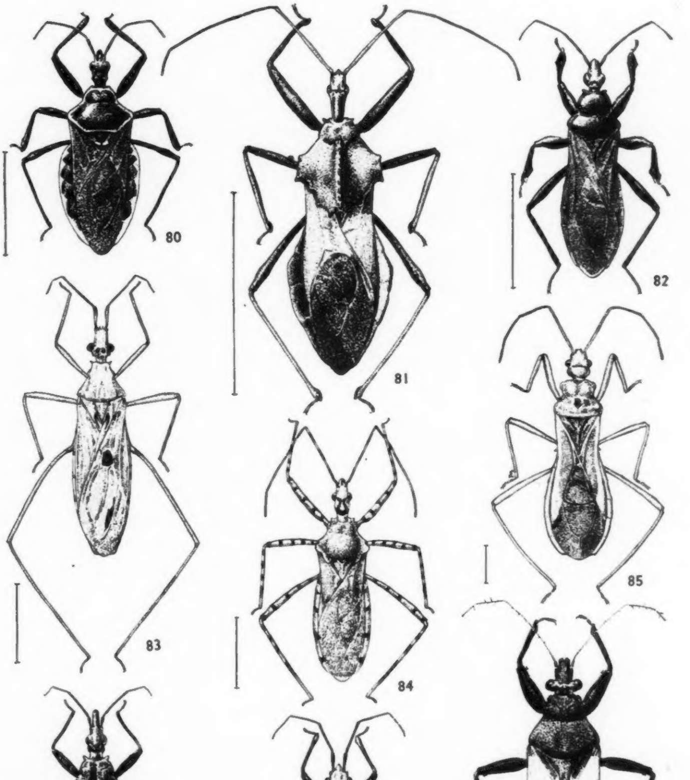

PLATE 8.—Fig. 80. *Apiomerus crassipes;* Fig. 81. *Arilus cristatus;* Fig. 82. *Melanolestes picipes;* Fig. 83. *Narvesus carolinensis;* Fig. 84. *Pselliopus barberi;* Fig. 85. *Oncerotrachelus acuminatus;* Fig. 86. *Triatoma sanguisuga;* Fig. 87. *Rhiginia cruciata;* Fig. 88. *Hammacerus purcis.*

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A Raptor Census in Montana

Robert W. Hiatt

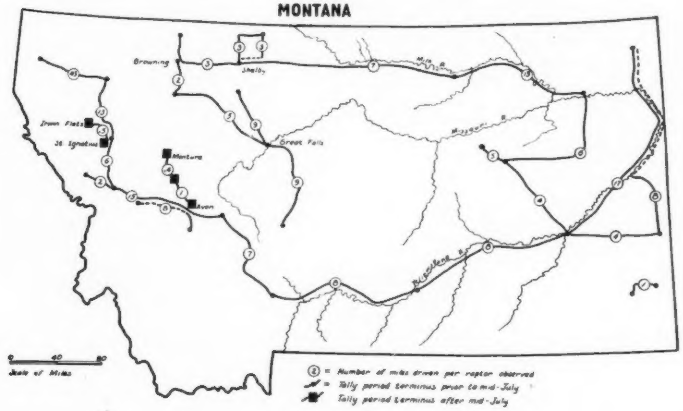
Raptors, by their size, conspicuousness, and majestic flight, are perhaps better known to ornithologists insofar as their occurrence and numbers are concerned than the majority of other avian groups. Previously published raptor censuses indicate that the road tally provides a useful medium by which to ascertain both the ranking of species as well as an index to their relative abundance. Nice (1921, 1922, 1931, and 1934) has employed the roadside census in raptor tallies through a large section of the United States, including areas in Massachusetts, Ohio, Chicago, Oklahoma, New Mexico, and Arizona. Baldwin, Kendeigh, and Franks (1932) in attempting to determine the relative abundance of raptors in Ohio, compiled a frequency total of observations upon raptors by a large number of ornithologists. The above observations were largely taken by the roadside census technique. Winterbottom (1933a, and 1933b) has likewise taken censuses on raptor populations from trains and motor cars in England, Gold Coast, and through much of South Africa. Recently, Leopold (1942) recorded all raptors observed from a car while travelling through Oregon, Nevada, and Utah.

The object of the present paper is to interpret the apparently dense Montana raptor population through the medium of an extended roadside tally. Therefore, in addition to analyzing what may well be the greatest concentration of birds of prey over a vast area of the United States, if not the entire continent, the present information adds materially to our knowledge of the ranking of the several raptorial species in Montana, and, to a lesser extent, serves to portray a quantitative index to these forms.

Observations were made over a total of 20 driving days during which 2459 miles were traversed over virtually the entire State (Fig 1). Our itinerary included, in addition to the main highways, many roads of secondary importance. Two observers riding in the front seat of an automobile tallied the birds.

Although roadside counts have numerous limitations which somewhat restrict their significance, it is believed that raptors more readily lend themselves to this type of census than many other avian groups. The soaring activity of the buteonine hawks, together with the perching habits of the accipiters and falcons provide an excellent opportunity for observation from a moving vehicle. The preference shown by Sparrow Hawks, Sharp-shinned Hawks, and Short-eared Owls for perching on fence posts and electric power poles is especially significant in Montana where open ranges are common, with fences and power lines usually placed along the main arteries for travel. It is obvious that a tally of this type records somewhat less than the total number of raptors present in the census strip. Raptors on the ground, in thickly foliated shrubs and trees, and on the nest are normally impossible to tally. Moreover, great discrepancies inevitably arise with regard to accurate presentation of frequency

data on owls. The nocturnal habits and diurnal sequestration of the majority of species render the roadside count virtually useless for this group. It must also be understood that this study in no way takes into account all raptorial species in the State, but rather, only those with habits of a type which would enable an observer to see them from a roadway. The reader is referred to Saunders (1921) for a list of raptors to be found in this area.



Data were recorded from June 9 to July 13, and from August 17 to 28, 1942, during the daylight hours. No owls flushed from roadways at night were included in the tally. No raptors observed while not driving were recorded. The widespread occurrence throughout the State of nearly all species recorded precluded the necessity of dividing the State into its three main geomorphological regions. It is obvious that some of the species are usually confined within rather narrow ecological limits, i.e., Burrowing Owls in the Prairie Dog towns of eastern Montana, and the Western Goshawk in the forested region to the west. However, the camas prairies and river valleys of the mountainous west provide sufficient Plains-type habitat to support the majority of species on a statewide basis.

The tally varied from seven to 98 raptors daily, with an average of 27. One raptor was observed for each 4.5 miles traveled. Daily species observations varied from one to seven with the average in excess of four. The total tally of 551 raptors observed during this census is analyzed by species in Table 1.

Almost exactly half of the hawks observed were Sparrow Hawks. This species was by far the most common one in Montana as well as in areas censused by the above-mentioned investigators. The Marsh Hawk ranks next with buteos occupying third place. Identical ranking was found in Ohio and the northwest (Baldwin, Kendeigh, and Franks, 1932; Leopold, 1942).

TABLE 1.—Analysis of the total number of raptors observed by frequency of occurrence.

Species	Number observed	Proportional per cent of total
Sparrow Hawk *(Falco sparverius)*	274	49.8
Marsh Hawk *(Circus hudsonius)*	102	18.5
Swainson Hawk *(Buteo swainsoni)*	56	10.1
Short-eared Owl *(Asio flammeus)*	45	8.2
Ferruginous Rough-leg Hawk *(Buteo regalis)*	29	5.3
Red-tailed Hawk *(Buteo borealis)*	12	2.2
Sharp-shinned Hawk *(Accipiter velox)*	6	1.1
Great Horned Owl *(Bubo virginianus)*	5	.9
Unidentified buteos	5	.9
Goshawk *(Astur atricapillus)*	5	.9
Burrowing Owl *(Speotyto cunicularia)*	4	.7
Prairie Falcon *(Falco mexicanus)*	3	.5
Golden Eagle *(Aquila chrysaëtos)*	3	.5
Pigeon Hawk *(Falco columbarius)*	1	.2
Osprey *(Pandion haliaëtus)*	1	.2
Total	551	100.0

Distribution in a quantitative manner is amplified by the frequency distribution map (Fig. 1). Caution must be used when comparing the frequency figures on a statewide basis. The major portion of the State was surveyed prior to mid-July, after which young birds of the year may be encountered. Those observations made during August will, therefore, include both adults and young. Such observations are specially differentiated on the frequency map. Three concentration areas are revealed by the figures shown between the tally termini. The first is located in that mid-western section of the State which is characterized by forested mountains interspersed with small river valleys and camas prairies. Remarkable concentrations of Sparrow Hawks were observed in the Upper Blackfoot Valley between Avon and Monture. The presence of myriads of grasshoppers was undoubtedly responsible for the localization of these birds in the rather restricted prairie-type topography. The hawks were actively engaged in catching the insects throughout the observation period. During the 57 miles traversed through this section almost two raptors per mile driven were observed. Of the 84 tallied in this locality, 85 per cent were Sparrow Hawks. A second area in this same general locality between St. Ignatius and Irwin Flats, a distance of 55 miles, supported two raptors per mile traversed. Approximately half the distance traversed an irrigated intermountain valley which provided excellent Marsh Hawk habitat, the remainder consisted of more arid grazing land which harbored a heavy infestation of grasshoppers. Of the raptors tallied on this trip, 51 per cent were Sparrow Hawks and 22 per cent were Marsh Hawks. The remarkable concentrations mentioned above comprised young of the year in addition to parent birds.

Nevertheless, the concentration found in these miniature intermountain prairies was the greatest encountered in Montana during the late summer season. There is little doubt that many of the Sparrow Hawks in these localities are merely vagrants which are attracted to the grasshopper hordes present in these isolated habitats during July, August, and September.

A second concentration area was found in the vicinity of Shelby and Browning. This region, composed of rolling hills immediately east of the escarpment forming the continental divide, is primarily grazing land. Grasshoppers were comparatively few in number while rodents, particularly the Columbian ground squirrel (*Citellus columbianus columbianus*) and the Richardson ground squirrel (*Citellus richardsoni richardsoni*) occur in vast numbers. The raptor species present sharply reflect the differences in prey fauna in contrast with the camas prairies farther west. The larger rodent-eating hawks predominate in this northern portion of the State. In this concentration area Swainson Hawks compose 35 per cent of the raptors, while Marsh Hawks and Ferruginous Rough-leg Hawks occur in a population frequency of 26 and 24 per cent, respectively. Sparrow Hawks comprise but two per cent of the total population observed.

The third concentration area was found in the extreme southeast section of the State. Unfortunately very few miles were traversed during suitable observation hours. However, incidental observations of raptors during grouse surveys in the area substantiated the fact that raptors are extremely abundant here, especially Marsh Hawks and the buteonines. Golden Eagles seem comparatively more abundant here than elsewhere in the State. Their presence may be associated with the relatively great jackrabbit concentration in this area. Sixty per cent of the raptors in this localization were Marsh Hawks while Sparrow Hawks comprised but 27 per cent of the raptors observed. Many buteonines were observed in the field but few from the road during the brief tally.

The study indicated that Sparrow Hawks predominate in both the mountainous west and river valleys of the south with Marsh Hawks in second place in the west, and Red-tailed Hawks occupying that position in the south. Marsh Hawks lead in frequency both along the northern and eastern boundaries of the State with Swainson Hawk second in abundance in the north, while Sparrow Hawks closely compete for first place in the east. In many areas along the northern and eastern boundary Marsh Hawks probably occur in a frequency of one pair per section of land. However, no figures are available to substantiate the actual incidence of occurrence. Incidental records obtained while censusing grouse in these localities would lead one to make an estimate of this magnitude.

Although localizations are apparent within the State, it is obvious that the statewide population might be designated as a macro-concentration area. For example, compare the statewide average of 4.5 raptors per mile traveled with those figures presented by Nice (1921, 1922) for Oklahoma which show one raptor observed for each 11 miles traveled. Yet, in 1934, this same area yielded but one raptor in approximately 45 miles driven! In the central and

southwestern states censused by Nice (1934) the average was one raptor for each 32 miles driven. When the results of the Ohio census are computed on a similar basis, we find one raptor for each eight miles driven. No recent data are available from this region. Leopold (1942) has shown that in the region just south of Montana, raptors occur on the average of one for each ten miles traveled. Inasmuch as this latter area is considered to be an outstanding concentration, it is then readily perceived that the Montana population is doubly remarkable and significant.

SUMMARY

1. Montana's remarkable raptor population has been analyzed in part by a species ranking and frequency distribution method based upon the road tally.

2. Aside from a few species which are confined to rather narrow ecological limits, the majority of raptors occur on a statewide basis. A total of 551 raptors were observed, for each 4.5 miles traveled. The tally varied from seven to 98 raptors daily, with an average of 27. A frequency of occurrence analysis of individual species indicates that Sparrow Hawks and Marsh Hawks are by far the most abundant, a fact which coincides with data published on other similar censuses in western United States.

3. Three concentration localizations are described, where raptors occur as frequently as two per mile traveled.

4. Sparrow Hawks predominate in western and southern Montana, while the Marsh Hawk is the most abundant species in the north and east. The distinct reflection upon raptor species occasioned by prey types present is indicated.

ACKNOWLEDGMENTS

I am indebted to Dr. P. L. Wright, Montana State University, for supplying tally figures for southeastern Montana, and for the area immediately north of Great Falls. The helpful criticisms provided by Dr. Jean M. Linsdale, Museum of Vertebrate Zoology, University of California, are gratefully acknowledged.

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MONTANA STATE COLLEGE,
BOZEMAN, MONTANA.

Sumac Fruit as a Food for Bob-white Quail

R. B. Nestler and W. W. Bailey[1]

The fruit of the Sumac (pronounced either "sū'mak" or "shū'mak") is considered by many persons as an excellent food for Bob-white quail (*Colinus virginianus*). Some farmers feel that so long as there is a supply of this shrub on the land, satisfactory food is available to support gamebirds through a siege of ice and snow.

According to Martin (1935:4), there are only two species of sumac significant as quail food in the Southeast: dwarf sumac (*Rhus copallina*), and smooth or white sumac (*Rhus glabra*). "Both species are shrubs or shrubby trees, common along roadsides, ditches, and clearings. They produce clusters of tart, red, berrylike fruits, which are available for quail practically every month of the year."

An authority on quail, Handley, in Stoddard's book (1931: 153, 154), states that Dwarf Sumac fruits, among other fruits, are utilized extensively by the Bob-white, even after drying. He points out from his observations, that Dwarf Sumac, although not eaten in so great quantities as a few other fruits, occurred oftener in the crops and gizzards examined (in 569 of the 1659).

> It was eaten during each month and formed more than 1 percent of the food from November to April, inclusive. In September, when the fruits were still fresh, the maximum for any month, 5.1 percent was taken. In February it was eaten fairly constantly and formed 4.2 percent of the food. A dependable observer saw one covey jumping up for the fruits. Possibly that they are obtained with difficulty explains why the dwarf sumac are not eaten in larger quantity. From a few to 25 fruits formed the average meal; only 32 birds had taken more than 100. The maximum number in one crop and gizzard was 515 seeds and 350 fruit skins. In a few instances a quantity of the fruit skins and no seeds were eaten.

Handley's figure for the percentages of sumac in the diet of quail during September and February, are averages, and consequently do not reveal the extreme cases. It will be noted that 32 birds had taken more than 108 sumac fruits at a meal, one yielding "515 seeds and 359 fruit skins."

Primarily during a critical winter period when the ground and shrubbery are blanketed with snow and ice, sumac fruit may be consumed in large quantities because often it is the only foodstuff available. According to Errington (1936:359):

> Stomach analyses and field observations during these time of food crisis show that, *with the exhaustion of staple foods available*, (italics ours) the quail tend to fill up on fruits of sumac (*Rhus* spp.), wild grape (*Vitis* spp.), rose (*Rosa* spp.), coralberry (*Symphoricarpos* spp.), and sundry others of fleshy consistency or composed principally of indigestible seeds.

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[1] Experiments were carried out by the Fish and Wildlife Service, U. S. Department of Interior in collaboration with the Bureau of Animal Industry, U. S. Department of Agriculture.

It is Handley's opinion that the seeds of dwarf sumac, "are utilized extensively as food and almost invariably ground up" (*op. cit.:* 154). "However, some investigators have found that during critical periods especially, large quantities of sumac have passed through the quail's alimentary canal undigested, as indicated by the droppings.

Errington (1931: 92, 93) ran a test with quail on a straight sumac diet (fresh fruits) for a week during winter. The birds lost an average of 5.7 grams per bird per day, in contrast with control quail, that gained .7 grams per bird per day on a corn and wheat diet. Errington concluded that, "Sumac is distinctly not everything that a winter quail food should be, which warrants contemplation in view of the prevalent tendency among ornithologists and sportsmen to estimate its value as a staple on the basis of its frequent or abundant representation in the stomachs of song and game birds." He warns that "no one should be deluded into any idea that the quail are 'all set' for winter merely because the stomachs are loaded with fruits," and emphasizes the fact that, "winter-killed coveys very often had hardly anything to eat but Sumac for days on end."

At the Patuxent Research Refuge, Bowie, Maryland, five tests were conducted to determine the value of dwarf and smooth sumac fruits, not only as the sole diet of quail, but also as a supplement to other feedstuffs. In two of the five tests the birds were force-fed; in the remaining three they were fed *ad libitum*.

Test no. 1: In the first test, two adult quail, in a battery unit, were deprived of food for 24 hours, and then force-fed 50 fruits of smooth sumac three times during the subsequent 48 hours. After a second period of 24 hours without food, the birds were sacrificed. In the case of one bird, post mortem revealed 21 sumac seeds and grit in the gizzard; in the case of the second bird, 31 sumac seeds and grit in the gizzard. Both birds had their caecae, or blind ducts of the intestines, packed with a mass of dark-bluish brown feces, of putty-like consistency. The rest of the intestines were empty except for 3 sumac seeds in the small intestine of one of the birds.

The droppings, which had become very hard upon drying, contained 164 sumac seeds, or 55 per cent of those eaten. Thus, only 45 per cent of the sumac seeds partaken by the birds had been digested.

Test no. 2: Six adult quail were placed in separate units of a quail battery, and deprived of food for 24 hours. Grit and water were supplied. On the second and third days of the test, bird A was force-fed 200 fruits of smooth sumac per day; bird B, 199 fruits of drawf sumac; bird C, a mixture of 100 fruits of smooth sumac and an equal volume of millet (red proso); and bird D, a mixture of 100 fruits of dwarf sumac and an equal volume of millet. Birds E and F were continued on the fast.

On the fourth day all the birds were deprived of food. Bird A died as a result of an obstructed windpipe. Her crop was well packed with fruits the gizzard contained about 24 sumac seeds, and the caecae held one.

After a period of 24 hours without food, birds B, C, and D, were sacrificed. The digestibility of the seed is shown in Table 1.

TABLE 1

Bird	Diet	No. of seed (all sumac) undigested in			
		Crop	Gizzard	Intestines	Droppings
A (died)	Smooth Sumac	....	....	....	75
B	Dwarf Sumac	0	46	3	139
C	Smooth Sumac and Millet	47	35	4	31
D	Dwarf Sumac and Millet	0	29	0	38

The seeds found in the crop of bird C, were still enclosed in the fruit-pulp. Apparently some impaction had taken place, although the bird appeared to be in normal condition prior to death. It had apparently digested 83 sumac seeds, or 54.2 per cent of those that had passed on to the gizzard.

Bird B, had digested 211 sumac seeds or 52.9 per cent of the total number fed; bird D, had digested 133 sumac seeds or 66.5 per cent of the total number fed. In the cases of both bird C and bird D, all the millet seed was digested.

On the fourth day of the test, a tray of sumac fruit of both the dwarf and smooth varieties, was placed before each of the two fasting birds, E and F. Large quantities of the fruit were eaten by the hungry quail. Within a period of three days, 825 seeds were excreted in the droppings.

On the seventh day equal quantities of dwarf sumac fruit and millet in separate feeders were given to the birds. Both feedstuffs were new to the quail. On the twelfth day a tray of maintenance mash was placed before each bird in addition to the sumac and millet. Table 2 shows the selection made by the birds.

TABLE 2

Days from start of test	Dwarf Sumac fruit	Millet	Mash
8 & 9	7 grams	49 grams	....
10	None	36 grams	....
11 & 12	None	56 grams	....
13 & 14	18 grams	55 grams	44 grams

During the period each bird consumed an average of 19 grams of feed per day. Of this amount, 1.8 grams, or 9.5 per cent, consisted of sumac fruit.

Test no. 3: Five yearling quail were placed in each of five units in a game-bird battery. Their diet was changed abruptly from a maintenance mash to the experimental diets, which were as follows:

Battery Unit No. 1—Smooth sumac fruit, whole
Battery Unit No. 2—Smooth sumac fruit, ground
Battery Unit No. 3—Smooth sumac seeds, ground
Battery Unit No. 4—Smooth sumac fruit-pulp, flaked
Battery Unit No. 5—No food
Battery Unit No. 6—Whole millet seed.

These feeds were placed before the birds to be eaten *ad libitum*. In Table 3, are given the average weights of the birds at the beginning of the test, and at the end of the second and fourth days, together with the quantity of feed consumed per bird per day.

TABLE 3

Type of Food	Feed consumed per day per bird		Weights of Birds		
	1st & 2nd Day	3rd & 4th Day	At Outset	After 2nd day	After 4th day
Smooth sumac Whole fruit	7.2	0	161	137	126
Smooth sumac Fruit ground	2.1	2.1	169	149	127
Smooth sumac Seed ground	2.2	8.7	171	151	134
Smooth sumac Fruit-pulp ground	2.6	0.7	173	151	124
No food	......	......	172	150	119
Millet	12.5	11.5	174	167	161

Normal feed consumption for quail maintained through the winter in holding pens is approximately 15 grams per bird per day. The feed consumption of the birds on millet was close to normal, whereas that of the birds on sumac feed, either fruit, pulp, or seed, was definitely subnormal. Millet was as new to the birds as sumac. During the third and fourth day the consumption of ground sumac seed improved considerably, whereas that of the whole fruit or the fruit-pulp practically ceased. During the 4 days of test, the birds on whole fruit lost 35 grams each or 21.7 per cent of their initial weight; those on ground fruit lost 42 grams each or 24.8 per cent of their initial weight; those on ground sumac seed lost 37 grams each or 21.6 per cent of their initial weight; those on sumac fruit-pulp lost 49 grams each or 28.3 per cent of their initial weight; those that received no food lost 53 grams or 30.8 per cent of their initial weight; whereas those on millet lost only 13 grams each or 7.5 per cent of their initial weight. The writers have noted that whenever quail are transferred from holding pens to battery units, there is a loss in body weight even though the diet is kept the same. Therefore, the slight loss on the millet seed probably should not be accredited to the feed.

At the conclusion of the test, a grain mixture was given to the birds. All the quail except those that had received millet rushed madly to the feeders and fought one another in order to obtain the grain.

Test no. 4: Five adult quail were placed in each of four battery units, and given the following diets:

Battery Unit No. 1—
Feed mixture "A" consisting of:
Ground yellow corn..............................34 parts
Ground wheat ....17 parts

Ground kaffir ....17 parts
Ground oat groats ....17 parts
Ground mammoth yellow soybeans....13 parts
Alfalfa leaf meal................................ 2 parts

Battery Unit No. 2—
Feed mixture "A" plus 1 percent sumac meal

Battery Unit No. 3—
Feed mixture "A" plus 10 percent sumac meal

Battery Unit No. 4—
Feed mixture "A" plus 25 percent sumac meal

The sumac meal consisted of one part of ground smooth sumac fruit and one part of flaked fruit-pulp. Grit, and a mixture of ground oyster shell and salt (4:1) were kept before all the birds in separate feeders.

During an eight-week test period, all the quail maintained their weight satisfactorily, and were in excellent condition at the close of the period (Table 4). It is interesting to note that the birds on the 25 per cent sumac actually gained slightly.

TABLE 4

		No sumac	1% sumac	10% sumac	25% sumac
Live weight (grams)	Beginning of test	171	171	169	170
	End of 8 weeks	165	163	163	171
	Gain or loss	—6	—8	—6	+1
Feed consumption per bird per day (grams)	Feed mixture	10.4	11.1	11.7	12.7
	Mineral	0.2	0.2	0.2	0.2
	Total	10.6	11.3	11.9	12.9

Feed consumption gradually increased as the level of sumac was raised to 25 per cent. The consumption of mineral was approximately the same for all four groups.

At the end of 8 weeks, the level of sumac meal in the diet for Battery Unit no. 2 was raised from 1 per cent to 25 per cent; that for Battery Unit no. 3, was raised from 10 per cent to 50 per cent; and that for Battery Unit no. 4, was raised from 25 per cent to 75 per cent.

During the first week after the change to new diets, the birds on 75 per cent sumac meal moulted their neck feathers. By the end of the fourth week, four of the five birds were dead. All had become emaciated. A post mortem of the dead birds disclosed no food in the crop or gizzard, and very little fecal material in the intestine except in the caecae which were packed with stiff putty-like feces.

Table 5, gives the results of the second phase of this test.

TABLE 5

		No sumac	25% sumac	50% sumac	75% Sumac
Live Weight (grams)	Beginning of 2d phase of test	165	163	163	171
	End of 4 weeks	168	162	157	131
	Gain or loss	+3	—1	—6	—40
Feed consumption per bird per day (grams)	Feed mixture	11.6	11.5	10.7	7.5
	Mineral	0.2	0.2	0.1	0.2
	Total	11.8	11.7	11.8	7.7

Feed consumption was the same for the diet containing no sumac, 25 per cent sumac, and 50 per cent sumac, but dropped 34 per cent for the diet containing 75 per cent sumac. The weights of all the birds except those in 75 per cent sumac held up well. During the first two weeks, the birds on 75 per cent sumac lost an average of 20 grams each, or 11.7 per cent of their initial weight.

The lone survivor of this diet was placed on a diet of 50 per cent dried buttermilk and 50 per cent ground yellow corn. In 2 days it gained 9 grams and was soon restored to normal condition.

Test no. 5: As a part of a larger experiment, sixteen adult quail were placed in each of two maintenance pens in November, and were kept on experiment 14 weeks. These birds were exposed to the weather, whereas those of the previous tests with sumac, were kept in batteries in a laboratory where the temperature was maintained at 70-75° F. One of the two pens received a diet consisting of 50 parts of flaked sumac fruit-pulp and 50 parts of a mixture of 92 per cent ground yellow corn, 10 per cent dehydrated alfalfa leaf meal, 4 per cent salt, and 2 per cent special steamed bonemeal. The second pen was given a choice of ten wild feedstuffs unground, and the four commercial feedstuffs mentioned above.

At the end of 14 weeks, all the birds were still alive and in good physical condition. The birds that received 50 per cent sumac fruit-pulp had gained an average of 14.4 grams per birds, while those on the "cafeteria" diet had gained 21.0 grams per bird. The feed consumption on the sumac diet was higher than for most of the other diets, each bird having consumed an average of 17.7 grams of feed per day during the test as compared with 13.5 grams by each bird on the "cafeteria" diet.

The birds that were given a free choice of feeds made the sumac fruit only 2.1 per cent of their diet for the 14 weeks. The largest quantity of sumac taken during test was not over 3.7 per cent.

A severe neck molt occurred among the birds on the sumac diet during the ninth week of the test.

In a recent study on the digestibility of corn, smooth-sumac fruit-pulp, and lespedeza (*L. sericea*) by quail, the results of which are expected to be published in the near future, it was found that caecal feces resulting from a sumac diet, were retained in a quail's body for several days after a change of feed, whereas those from corn or lespedeza were defecated within 24 hours. Also, whereas the ratio of corn consumed to the resulting feces was approximately 3:1; the ratio of sumac fruit-pulp to the resulting feces was ½-1. In other words the quail on sumac excreted about twice as much fecal material as the material they consumed, the feces having absorbed a copious quantity of water.

DISCUSSION

Recent chemical analyses of wild feeds by King and McClure[2] gave the following average composition for dry sumac fruit, seeds, and pulp.

TABLE 6

	Crude Protein	Crude Fiber	Nitrogen-free extract	Fat	Calcium	Phosphorus
Dwarf sumac seed	12.43	27.64	38.96	12.00	0.13	0.34
Dwarf sumac fruit pulp	4.61	19.53	54.50	10.24	0.80	0.09
Dwarf sumac fruit	7.75	26.93	40.46	16.20	0.15	0.15

When one compares the high fiber content of sumac with that of some bulky commercial feedstuffs used in the feeding of poultry, such as, wheat bran, 9.0 per cent fiber, dried grapefruit refuse, 11.6 per cent fiber, and peanuts with hulls, 17.8 per cent fiber, one can readily appreciate why it may be difficult for quail to maintain life for several days on sumac pulp alone, especially during severe winter weather.

However, this analysis reveals also that the pulp is a good source of calcium, equal to dried whey. There is a possibility too that sumac may supply certain vitamins to game—this possibility remains to be investigated. Thus although sumac as the sole feedstuff in a diet, apparently is a very poor energy food in comparison with such feedstuffs as corn or millet, nevertheless, in small quantities it may have an essential place in the diet.

SUMMARY AND CONCLUSION

Five feeding tests were conducted at the Patuxent Research Refuge, Bowie, Maryland, to determine the value or dwarf and smooth sumac fruits as the sole diet of quail, as well as a supplement to other feedstuffs.

When whole sumac fruits were force-fed quail, either alone or in combina-

2 Thomas R. King, Virginia Cooperative Wildlife Research Unit, and Harold E. McClure, Bureau of Animal Industry, U.S.D.A. (unpublished data).

tion with millet seed, many of the sumac seed were defecated undigested, whereas the millet seed was digested. Likewise, many sumac seed passed through the quail undigested when sumac fruit was fed *ad libitum* subsequent to a fasting period.

The quail did not relish sumac fruit as the sole article of diet. They lost weight nearly as rapidly on the fruit, ground or whole, the ground seed, or the pulp as they did when not given any food.

Quail maintained their weight for 14 weeks during the late fall and winter in outdoor pens on a diet containing 50 per cent sumac fruit-pulp and other feedstuffs of high feeding value. A severe neck molt, however, occurred during the ninth week.

Quail lost weight rapidly on a diet containing 75 per cent sumac even though kept away from adverse weather conditions. A severe neck molt took place during the first week of this high-sumac diet. Heavy mortality occurred during the third and fourth weeks.

Where the birds had a choice of many feedstuffs, they made sumac fruit 2 to 4 per cent of their diet.

Therefore, it must be concluded, that even though sumac fruit is eaten by quail, and as a small percentage of the diet it may have a definite nutritional value, nevertheless as the sole or primary article of diet, it cannot be expected to maintain quail through a critical period in the winter.

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The Range Vegetation of Kerr County, Texas, In Relation to Livestock and White-tailed Deer[1]

Helmut Karl Buechner

CONTENTS

Introduction

The Problem

The present paper deals with biotic investigations of the vegetation, livestock, and deer in Kerr County, Texas. The nature of the problem was twofold: first, to make an extensive field reconnaissance of the vegetation, supplemented by intensive studies on various ranches; and second, to determine the relationships of livestock and deer to the vegetation as a basis for range management plans.

The investigation was motivated by the high commercial value of range lands in Kerr County, both for livestock (cattle, sheep, and goats) and deer production. In addition to large numbers of cattle and sheep, over 80 percent of the goats in the United States are found on the Edwards Plateau, where the county is located. Moreover, Kerr County is one of the few sections of the country in which direct and substantial monetary returns are received from deer. If the high economic value of the land at the present time is to be maintained, it is important that the range vegetation and soils be not permitted to deteriorate. In view of the fact that some of these range lands are decreasing in productiveness, the present study was undertaken to determine the underlying causes and to serve as a basis for land improvement.

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1 The present paper is based on a thesis submitted in partial fulfillment of the requirements for the degree of Master of Science at the Agricultural and Mechanical College of Texas, College Station, Texas.

METHODS OF INVESTIGATION

The data here presented were derived from field studies conducted between May 16, and November 20, 1942, a period of six months. Investigations were both extensive and intensive in nature. Three hundred and seventy-five vegetative quadrats were temporarily established; and records made of floristics, estimates of crown coverage by species, the structure of the vegetation, effects of browsing and grazing, soils, and physiography. All the roads in the county (approximately 300 miles) were covered in mapping and making supplementary notes on the vegetation. While studies of livestock and deer in relation to the plant cover were carried out primarily on four ranches, pertinent observations were made throughout the county.

The method employed in vegetative studies is that of Egler (1940). Vegetative plots of three kinds were established: a five-acre quadrat on which species were listed for presence; a one-quarter-acre quadrat on which crown coverage of trees and shrubs by species, as well as total browse, were estimated; and a one-hundred-square meter quadrat on which the coverage of grasses and forbs was estimated. These temporary quadrats were placed at random in selected pastures under particular grazing conditions. The data from these quadrats were assembled in "presence and coverage-when-present" tables.

In studying white-tailed deer, *Odocoileus virginianus texanus* (Mearns), three ranches, each representing a particular vegetative type and a different intensity of livestock grazing, were selected and the density of the deer population determined. The census method employed was that of Erickson (1940), and is a modification of R. T. King's method for censusing ruffed grouse. Eight miles of cruise line, consisting of three lines, each two miles long and one-half mile apart, were surveyed with a hand compass and by pacing. These cruise lines were marked with blazes on trees and flags of bright orange cloth, making possible a series of counts covering the same area. Each census determined the population on two sections of land; number of acres per deer and number of deer units[2] per section were then calculated. Three counts on each area, taken under similar weather conditions, were found to be sufficient to secure a reliable average.

Information concerning present livestock management was secured through interviews with various ranchmen. Data dealing with the effects of livestock on the range vegetation were obtained through observations and correlations with stocking records of ranchmen.

ACKNOWLEDGMENTS

I wish to express my indebtedness to Dr. Walter P. Taylor, of the Texas Cooperative Wildlife Research Unit and the Department of Fish and Game, Agricultural and Mechanical College of Texas, under whom this study was carried out, for his supervision both in the field and during the preparation of the present paper. Grateful acknowledgment is also due V. L. Cory of the Substation No. 14, Texas Agricultural

2 The animal unit, as used here, is based on the dry weight forage consumption of a 750 pound mother or breeding cow. According to Youngblood and Cox (1922), 7 sheep or 8 goats are equivalent to one animal unit. Taylor and Buechner (1942) have shown that 6 Kerr County deer are equivalent to one animal unit.

Experiment Station, Sonora, Texas for the identification of plants; Henry C. Hahn of the Texas Game, Fish and Oyster Commission for his helpful comments and suggestion in the field; and the following ranchmen who not only placed their lands at my disposal, but also supplied pertinent information concerning livestock, deer, and past history of the vegetation: Adam Wilson II, Louis Real, Felix Real, Walter Real, Clarence Hyde, Eugene Cowden, and Eddie C. Henke.

Previous Investigations

Because of its unique physiography, vegetation, and animal life, Kerr County has attracted the attention of botanists and zoologists at least since 1882, when Howard G. Lacey first began his work on birds and mammals. Initial investigations of the vegetation were made by Bray (1901, 1904, 1906), who included the Edwards Plateau in his studies. Though of limited extent in this region, Bray's work is of great value, and extensive reference has been made to it in the present paper. Most biological investigations in Kerr County have dealt with birds and mammals. At the present time the Texas Cooperative Wildlife Research Unit and the Texas Game, Fish and Oyster Commission are carrying out studies of the Rio Grande turkey *Meleagris gallopavo intermedia* Sennett, and white-tailed deer. These studies concern life history and management. Those sponsored by the Texas Cooperative Wildlife Research Unit are under the immediate direction of Walter P. Taylor. Field studies for the Texas Game, Fish and Oyster Commission are under the supervision of Phil D. Goodrum of the Federal Aid program, the field work having been done by Eugene A. Walker and Henry C. Halm.

Habitat Factors

As used here, habitat factors refer only to the inorganic chemical and physical factors of the environment, in the sense of Clements and Shelford (1939).

CLIMATE

The climate of Kerr County is decidedly more xeric than that of the lower elevations of eastern Texas, though not as dry as the plains in the western part of the state. The precipitation-evaporation graph (Fig. 1), constructed from climatic records taken at the weather station located in Kerrville, indicates that evaporation constantly exceeds precipitation throughout the year. Temperatures average 80.8° F. in July; 48.8° in January. Although the average annual rainfall is 30 inches, little of this water is available for plant growth; xerophytic conditions are intensified by high winds that accelerate the removal of water from the soil and from plants.

The continental climate of Texas is characterized by rapid changes and marked extremes, both in temperature and moisture. A wide daily, seasonal, and annual amplitude of temperature and rainfall is characteristic. Severe droughts, causing great damage to agricultural crops and livestock ranges, occur periodically; and destructive floods are by no means unknown.

Although the average number of days between killing frosts is 221, this cannot be considered the actual growing season, since the amount of available moisture, rather than temperature, controls the length of the growing season. During the droughty conditions of midsummer, plant growth is at a mini-

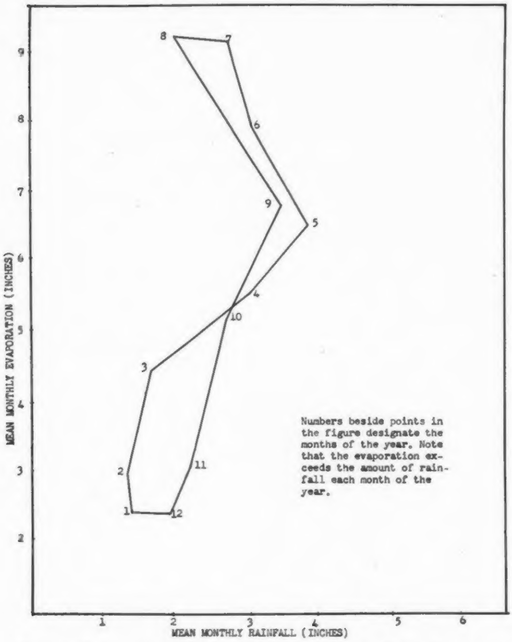

Fig. 1. Precipitation-Evaporation Graph for Kerr County

mum; some species of plants make most of their growth in winter.

Thornthwaite (1931) places Kerr County in the subhumid climatic province and indicates a deficiency of precipitation at all seasons. According to his classification of the climates of North America, this region should support only grasslands, except along streams. Because of the physiographic and soil influences, however, the natural vegetation of the county is an oak-savanna.

PHYSIOGRAPHY

Kerr County is located between the 99th and 100th meridians; 30° north latitude passes approximately through the center of the county. Its physiography is typical of the Edwards Plateau, a stratum plain (Fenneman, 1931) that forms the southern termination of the Great Plains (see Fig. 2). On the south and southeast, the Edwards Plateau is limited by an out-facing escarpment. This distinct, but much dissected Balcones Escarpment, extends approximately from Austin to San Antonio and west to the Rio Grande, and is made up of many small faults. Much erosion has taken place along the escarpment, extending through about the eastern third of Kerr County.

Three simple topographic elements are found in the Edwards Plateau

(Hill and Vaughan, 1897): (1), the flat topped summits of the decaying plateau; (2), the breaks or slopes of its crenulated borders; and (3) the stream ways. Approximately the northwest quarter of Kerr County is known as the "divide" country, and is nearly identical with the unbroken portions of the plateau. Such valleys as exist at the headwaters of the main streams cutting into the plateau are only wide "draws" (shallow valleys without streams) which carry only storm waters or none at all. There are a few shallow depressions or sinks on the plateau that occasionally retain water a short time. In draws percolation is large. Where larger than ordinary, often where several draws meet, there may be a depression or "grass valley" with or without a visible outlet. Typical valleys of this type are found on the Y-O

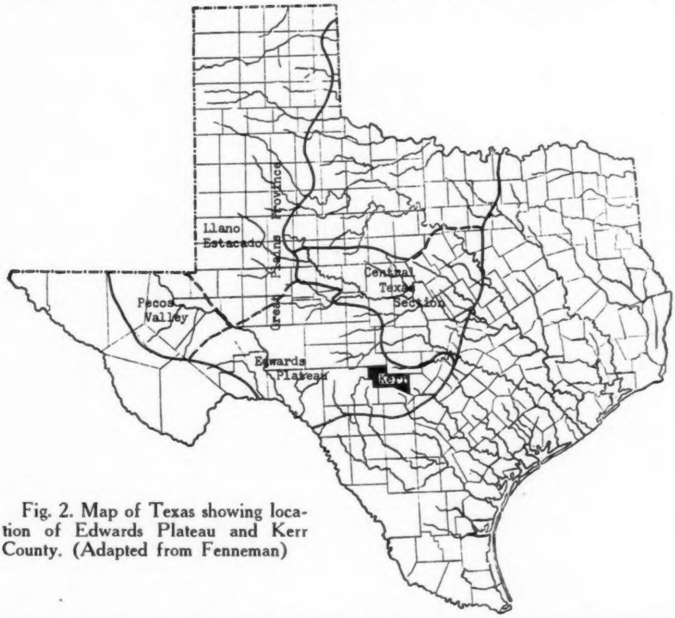

Fig. 2. Map of Texas showing location of Edwards Plateau and Kerr County. (Adapted from Fenneman)

ranch in northwestern Kerr County where they are characterized by liveoak (*Quercus virginiana*)[3] and mesquite (*Prosopis juliflora* var. *glandulosa*). Southward and eastward Kerr County is dissected by streams, varying from V-shaped valleys at the headwaters in the western part to the broad Guadalupe Valley in the eastern portion. Erosion has cut through the hard Edwards limestone of the plateau in the eastern part of the county, leaving many hills. The southwest-central portion of the county is a narrow divide between the Medina and Guadalupe watersheds. Elevations of the county vary from 1500

3 Names of plant species follow the *Catalogue of the Flora of Texas* (Cory and Parks, 1937).

feet along the Guadalupe Valley below Comfort to 2300 feet on the divide.

Most of the drainage of the county is eastward by the Guadalupe River and its tributaries, although some drainage is into the Frio and Medina watersheds on the south, and the Llano watershed on the north.

Soils

No adequate treatment of soils is available for Kerr County. A reconnaissance soil survey was made by the United States Department of Agriculture Bureau of Soils in 1913 (Whitney,1916). A large portion of the county, particularly the divide, is composed of rough stony land, derived from Edwards limestone. Although such soils are thin and rocky, they are apparently extremely rich in nutritive value. The clay loam soils derived from Edwards limestone are deep chocolate in color in contrast to the whitish caliche soils derived from the soft Walnut geological formation found beneath the Edwards formation. In grass-covered valleys on the divide, the soils are considerably deeper than elsewhere on the uplands. Only in the broader valleys, such as those of Turtle Creek and the Guadalupe River, are soils of sufficient depth for extensive agriculture.

Anthropic Influences

In most parts of the North American continent, before the advent of white man, man probably had little or no influence on the vegetation or animal life; indeed, he himself was an integral part of the animal life. The American Indian lived on plants and wild animals, and seemingly by instinct interfered but little with natural conditions, perhaps to maintain and perpetuate the wildlife and vegetation at his disposal. But the Edwards Plateau was a notable exception to this general scheme, since the Indian burned the vegetation periodically to facilitate hunting by routing out the game and increasing its visibility. The effect of this practice was to destroy tree and shrub seedlings and produce a grassland in regions that would otherwise have supported arborescent vegetation. During the time when the region was a grassland, white-tailed deer were probably less numerous.

Settling of the Edwards Plateau region was long delayed because of the arid climate, rough topography, and thin soils, a combination of factors that made agriculture impossible except along the main streams. As pointed out by Real (1942), Kerr County was first settled about 1846 by shingle makers who utilized the large cypress trees along the Guadalupe River. By 1850 settlers had occupied practically all the agricultural lands in Texas eastward and southward of the plateau. The overflow migrated to the Edwards Plateau, took up large tracts of land, and made ranching a means of living. Fences were unknown before 1883; the cattle of various ranchmen roamed together on a "free range." As definite boundaries of ownership became established with the advent of the Texas-Pacific Railroad in 1882, ranchers began fencing pastures. Equally as important in the development of fences was a gradual shift from cattle to sheep, necessitating wolf-proof fences.

As a result of the elimination of fires and the introduction of livestock, profound changes took place in the vegetation. What was once a waving sea of grass as far as the eye could see was changed to a diversified arborescent

vegetation. At the present time the effects of the livestock industry are the most significant influence of man on both vegetation and animal life.

Past History of Vegetation and Livestock

VEGETATION

As stated by Bray (1904), both agriculture and grazing have operated to prevent the recurrence of prairie fires, which, so long as they were recurrent over short periods, kept the field swept clean of woody vegetation. Grass throve under this burning; seedlings of trees were killed. Some of the early settlers, still living in Kerr County, tell of the tall grasses that covered both the hilly eastern part of the county and the divide alike, the monotony being broken only by occasional cedar brakes (dense growths of *Juniperus ashei*) on extremely thin clay soils at the headwaters of streams and by tall trees along streamways. Since little bluestem bunchgrass (*Andropogon scoparius* var. *neomexicanus*) is the only known tall grass of abundance in the region at the present time, it is assumed that this was the species which covered most of the land. Coincident with the elimination of prairie fires, both agriculture and grazing resulted in breaking up the heavy sod covering which was also a limiting factor to tree growth, agriculture by turning under the sod, grazing by killing out grass through overpasturing. The neglected field and the overgrazed, trampled pasture then became inviting territory for invasion of forbs (weeds) and woody growth.

Except along streams where tall cypress (*Taxodium distichum*), walnut (*Juglans major*), pecan (*Carya pecan*), elms (*Ulmus* spp.) and sycamore (*Platanus occidentalis*) were found, dense cedar brakes were the most characteristic arborescent vegetation of the erosion area of the Edwards Plateau before this region was settled by white man. Two factors operated to prevent the burning of cedar, its position and the substratum. The heads of the steep V-shaped valleys where cedar occurred provided wind protection, accounting in part for protection from fire. Furthermore, fires usually spread on the uplands or grass-covered slopes, moisture conditions along streams being sufficient to retard or stop the fires. Since the natural tendency of fire is to burn uphill, fires were slow to spread downhill into cedar brakes, if at all. Supporting such restriction by physiographic position was the almost soilless limestone debris on which the cedar grew. There usually was an insufficient supply of fuel for ground fires to become severe enough to develop the crown fires which would have destroyed the cedar.

Occurrence of cedar, rather than other arborescent vegetation, was caused primarily by the adaptiveness of cedar to thin limestone soils and the absence of competition from other woody species less, or not at all, adapted to such edaphic conditions. In all probability small quantities of Lacey oak (*Quercus laceyi*) also existed in cedar brakes, since the present studies indicated it to be nearly as well adapted as cedar to unfavorable edaphic and physiographic conditions.

With the removal of fire and introduction of livestock, marked changes took place in the vegetation. Not only did the absence of fire permit growth of tree seedlings, but the effect of livestock in reducing competition from

grasses by grazing and trampling, disseminating seed, and causing root suckering also favored tree growth. Land that had been covered by little bluestem grass was transformed into large cedar brakes and oak savannas, the cedar appearing in the less favorable physiographic positions and edaphic conditions, while the oaks occupied more favorable situations. But cedar was by no means restricted to thin limestone soils. Through distribution of seed by livestock, birds (especially robins), and wild mammals, its lack of palatability to livestock and deer, and the reduction of grass competition mentioned above, cedar invaded lands of all types, including bottomlands, slopes, and summits. Thus favored by livestock, a profound human influence, cedar spread on land that would otherwise have supported the more valuable oaks and grasses. It is of interest to note that cedar berries were widely disseminated by wild birds and mammals long before white man made his appearance, and that only after fires were eliminated and competition from grasses reduced did cedar spread over the land. Ranchmen were forced to reduce their stock, severely overgraze land not covered by cedar, or to try to control the cedar by expensive cutting operations.

Invasion of the former grasslands by oaks was influenced by the physiographic and edaphic requirements of the individual species, the oaks segregating on this basis into distinct types (see page 708).

Changes in grass cover were also marked, being conditioned almost entirely by grazing. In the composition of grass formations, Smith (1899) observed that before the ranges were overgrazed, the grasses of central Texas were largely bluestems or sage grasses (*Andropogon*), often as high as a horse's back. After pasturing and subsequent trampling and hardening of the soil the dog grasses or needle grasses (*Aristida*) took the whole country. After further overstocking and trampling the needle grasses were driven out and the mesquite grasses (*Hilaria* and *Buchloe*) became the most prominent species. Evidence gathered during the present study proves definitely that needle grasses (or three-awn grasses) are below curly mesquite and buffalo grass in ecological succession. Smith's observations are, nevertheless, of value in showing the trend in retrogression that is still not common knowledge among ranchmen. The result of grazing was to produce a grass cover that is now a mosaic of various combinations of species, limited mostly by fences and varying with different intensities of grazing. Found in abundance only in a few protected pastures and parks, little bluestem has been greatly reduced. Predominant grasses are now speargrass (*Stipa leucotricha*), curly mesquite (*Hilaria belangeri*), several species of three-awn, and muhlenbergia (*Muhlenbergia* spp.).

LIVESTOCK

In her history of Kerr County, Real (1942) indicates that cattle were brought into the county about 1850; sheep were brought in during the fall of 1857, but the sheep industry was in an experimental stage until 1875. Goats were introduced about 1880, and went through a similar experimental period. According to Smith (*op. cit.*) cattle were first introduced in most of central Texas about 1860, and by 1874 the industry was booming. The following ten years was known as the "golden period;" in 1884 the period of speculation

had reached its peak, and ranges showed serious shortages of grass as a result of overstocking which was often 300 to 500 cattle (or animal units) to 640 acres. Bentley (1898) states that as early as 1867 a few scattered sheepmen were found along the drier uplands, where there was a shorter and richer growth of forage.

In explaining the changes that took place in carrying capacity[4] through overgrazing even before 1900, Bentley (*ibid.*) refers to stockmen who tell of grasses that were everywhere from 1-3 feet high, and sometimes as high as a cow's back. Such grasses were found not only on the bottom lands, but also in places on the drier uplands. At that time the ranges would have supported 300 head of cattle to the square mile. Bentley goes on to say that after thirty years (1868-1898) almost every condition changed. The carrying capacity of the range steadily decreased until it was an exceptional property that could carry one head of stock to 5 acres. That was the common average in 1888, and in 1898 it required at least 10 acres per head, though it was not considered good policy to place more than 50 cows on one section of 640 acres. During the golden period from 1874 to 1884 the chief cause for overgrazing was an exceptionally favorable market. An added incentive after 1882, when the final survey of the Texas-Pacific Railroad was being made through central Texas, was the necessity of establishing definite boundaries of ownership. By trying to gain wealth quickly through making the most out of their opportunities while "free grass" was still available, ranchmen overstocked greatly. The overstocking continued year after year, through good seasons and bad ones, until it was the opinion of some of the most experienced cowmen of central Texas that the injury had gone almost past the point where redemption was possible.

It is of interest that the range in central Texas has never recovered from this early disastrous overstocking. The ranges continue to support about one-tenth of the number of livestock that were grazed in the decade of 1874-1884. The technical agencies most familiar with the problem recommend not more than 50 animal units of livestock per section on these ranges, as compared with the former 300 to 500 (see Youngblood and Cox, 1922; pp. 163-168; Cory, 1927; pp. 5-6; Taylor and Buechner, 1942). This significant situation affords food for thought as to the present and future needs of the area.

With the decrease in favorable grasses through overgrazing and the growth of trees and shrubs, sheep and goats became more profitable to ranchmen than cattle. On the theory that sheep consume forbs to a large extent and goats utilize browse, while cattle feed almost entirely on grass, all three types of livestock were usually pastured together, though little attention was given to the proper proportions of each or the maximum total that the vegetation could support without deterioration. This resulted in more devastating effects from overgrazing than would otherwise have occurred, since some of the highly

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4 Carrying capacity, following Jardine and Anderson (1919), refers to the maximum number of stock which a unit of land will support each season over a period of years without injury to the range, tree, growth, or watershed, or unwarranted interference with game. In this paper it is expressed as the number of animal units to the section of 640 acres.

desirable species, such as little bluestem and some of the grama grasses, were seriously overused and often completely eliminated. At the present time this practice of triple use continues, with attention gradually, though slowly, being directed toward the problem of proportions of livestock of different classes as well as maximum numbers in each pasture.

Although deer are extremely abundant, indeed, often overabundant, on many ranches, and substantial quantities of browse and grasses are consumed by these animals, in only a few cases has allowance been made for them in stocking programs.

Present Vegetation

Physiognomy

The vegetation of Kerr County varies from tall cypress and elms along streams to dwarf shrub-like oaks on the highest points of the divide and the summits of hills; from closed Spanish oak (*Quercus texana*) forests without understories to open, park-like blackjack (*Quercus marylandica*) and liveoak savannas, and clumps of oak set in open savannas. The physiognomy depends on physiographic conditions such as slope, elevation, geological formation, and drainage; edaphic conditions such as depth, type, texture, and acidity of the soil; moisture relationships brought about by character of the soil and topography; and the physiological tolerance of the individual species. On the basis of these habitat factors and habitat requirements, several physiognomic types of vegetation were recognized, as mentioned at the beginning of the present discussion. However, not only physiognomy, but also homogeneity of floristic composition and dominance of certain species were considered in designating the vegetative communities here discussed. The growth form of blackjack, for example, was often similar to that of Spanish oak in forming closed forests, yet the two species fall into two separate communities because of their associated species. Moreover, the two species are segregated into two physiographic habitats, the former being usually found on small, narrow divides, the latter on slopes or in draws.

The xerophytic nature of the climate is expressed in the entire vegetation of the Edwards Plateau. Dwarfing of tree species is the most conspicuous effect of the aridity, the degree of dwarfism varying from cypress and sycamore 60 to 70 feet tall along streams to Spanish oak 10 to 20 feet tall on slopes, and finally shinoak (*Quercus breviloba*) 2 to 6 feet tall on the divide and summits of hills. Correlated with lack of moisture also are slow growth, small leaves and buds, and more or less thin crown canopies. Dense or "closed" crown canopies sufficient to exclude light and prevent the growth of grasses are found to a considerable extent in the riparian vegetation and in blackjack, Spanish oak, and cedar communities, presenting a serious management problem; but usually in all the communities sufficient light is available for growth of grasses and forbs.

Succession

Proper range management of livestock depends upon an accurate knowledge of recognizable seral stages and their position in succession. In Kerr County these stages are believed to be established substantially as presented below. Little evidence of tree succession was found. There was however, a defi-

nite secondary succession among the grasses and herbaceous species. Floristic composition of the various stages will be presented and discussed under the communities in which they fall. Following is a list of the seral stages in retrogressive order with the principal indicator species:

1. Climax or Little Bluestem Stage.
   Little bluestem; speargrass; some muhlenbergia *(Muhlenbergia lindheimeri)*, silver beardgrass *(Andropogon saccharoides)*, and sideoats grama *(Bouteloua curtipendula)*.
2. Perennial Tall Grass or Grama Stage.
   Sideoats grama, little bluestem, silver beardgrass, hairy grama *(Bouteloua hirsuta)*, blue grama *(Bouteloua gracilis)* and dropseed *(Sporobulus asper* var. *hookeri)*.
3. Perennial Short Grass or Curly Mesquite or Buffalo Grass Stage.
   Buffalo grass *(Buchloe dactyloides)* (moist habitats); curly mesquite (drier habitats); some sideoats grama, hairy grama, and Texas grama *(Bouteloua rigidiseta)*. Some forbs such as *Evax* spp., pepper grass *(Lepidium virginicum* var. *corma pusillum)*, and small-flowered verbena *(Verbena bipinnatifida)* may appear under heavy grazing.
4. Perennial Three-awns and Forbs or Three-awn Stage.
   Three-awn grasses, Texas grama, hairy triodia *(Triodia pilosa)*, *Limnodea arkansana*, buffalo grass and curly mesquite more or less sparse, prickly pear *(Opuntia lindheimeri)*, yucca *(Yucca* spp.*)*, small-flowered verbena, *Evax* spp., pepper grass, and Mexican tea *(Croton monanthogynus)*.
5. Perennial and Annual Forbs or Forb Stage.
   Buffalo grass and curly mesquite scattered or absent, hairy triodia, some three-awns, hoarhound *(Marrubium vulgare)*, mealy sage *(Salvia farinacea)*, *Evax* spp., pepper grass, small-flowered verbena, plantain *(Plantago rhodosperma)*, *Tragia* spp., *Cassia roemeriana*, nightshades *(Solanum* spp.*)*, prickly pear, yuccas, and *Euphorbia* spp.
6. Bare Ground Stage.

The succession presented above occurs on relatively deep soils in bottomlands, on gentle slopes, on divides, and on the summits of hills. Several modifications are evident. On slopes over ten degrees and on extremely thin soils the third stage is conspicuously absent, neither buffalo grass nor curly mesquite grass being physiologically tolerant to thin soils and severe erosion on moderate to steep slopes. Both of these short grasses reproduce principally by runners when subject to grazing; the runners require deep soil free from severe erosion.

Another departure from the usual secondary succession is found under the heavy shade of blackjack and post oak (*Quercus stellata*) stands. Here curly mesquite and buffalo grass are replaced by speargrass which is tolerant to the shade, moisture, and soil conditions found under the canopy of blackjack and post oak. Curly mesquite and buffalo grass require a considerable amount of sunlight, and in the blackjack community these grasses are found only in large open areas three acres or more in extent. Speargrass, by reason of its tolerance to conditions within the blackjack community, its high position in succession, and relatively low palatability, often forms nearly pure stands that persist indefinitely in such areas under a wide range of grazing pressure.

A third modification is found in small swales that lead out of draws at the lower elevations in eastern Kerr County. Here moisture is retained by caliche soils during rains, especially in the spring and fall. Two species of muhlenbergia, *Muhlenbergia lindheimeri* and *M. utilis*, are well-adapted to the heavy clay soils and periodically wet conditions. These species offer considerable competition to andropogons and no evidence has been found that little blue-

stem grass is the climax dominant in such habitats, although it occurs to a slight extent in mixture with the muhlenbergias. Undoubtedly little bluestem, usually closely cropped, would be present in greater abundance if grazing pressure were reduced.

Smith (1899) indicated that three-awn grasses stand above curly mesquite and buffalo grasses in succession; but the present study has shown that in Kerr County, at least, the situation is reversed and that on the basis of their ecological requirements the three-awn grasses are below curly mesquite and buffalo grass. The short grasses occupy the better ecological habitats; the three-awn grasses compete and dominate only on the poorer habitats, unless overgrazing eliminates the more palatable short grasses. Furthermore, during progressive succession, three-awns follow bare ground and forbs, and are succeeded by the short grasses. With overgrazing the buffalo and curly mesquite grasses are eliminated and the vegetation is thrown backwards to the three-awn stage. There exist two possible reasons why Smith and others place the short grasses below the taller three-awns: first, there is a natural tendency to place short grasses below tall grasses on seemingly logical physiognomic grounds; second, when pastures in curly mesquite are suddenly subjected to heavy overgrazing (100 or more animal units per section) the three-awn stage is omitted and retrogressive succession is direct from curly mesquite to unpalatable forbs and bare ground.

SEGREGATION

On the basis of physiographic and edaphic factors, there exists a distinct segregation of the various species of oak, together with other closely associated species. Liveoak is found on deep, rich soils in bottomlands, on the lower, gentle slopes, and at higher elevations on the divide and on the summits of hills in the eastern part of the county. Spanish oak occurs on slopes of 10 to 60 degrees or more in the hilly section of eastern Kerr County and in draws and heads of V-shaped valleys of the main divide and smaller divides. Lacey oak grows in the draws and on the most precipitous slopes of all. Shinoak is practically always found at the higher elevations on the divides and hill tops. Blackjack and post oak occur on smaller divides, rarely on the main divide and at lower elevations in the bottomlands.

Such definite segregation seems to indicate that the present distribution of the oaks will remain indefinitely.

Cedar, on the other hand, shows no correlation with physiography or soils, undoubtedly because this species is controlled by livestock in its distribution. It is found on bottomlands, slopes, divides, and summits alike.

PRINCIPAL VEGETATIVE AREAS

The vegetation of Kerr County may be divided into five main areas, as follows (Fig. 3):

1. The Liveoak-Shinoak Divide (main divide in northwestern part of the county—34 percent of the county).
2. The Blackjack Divide (narrow divide between Medina and Guadalupe watersheds—4 percent of the county).

3. The Liveoak-Spanish Oak Erosion Area (eastern part of the county —37 percent).
4. The Cedar Brakes (central and south-central parts of the county—24 percent).
5. The Riparian (1 percent).

The communities of each of these areas will be discussed as to floristic composition, dominant species, structure, succession, and value to livestock and deer management.

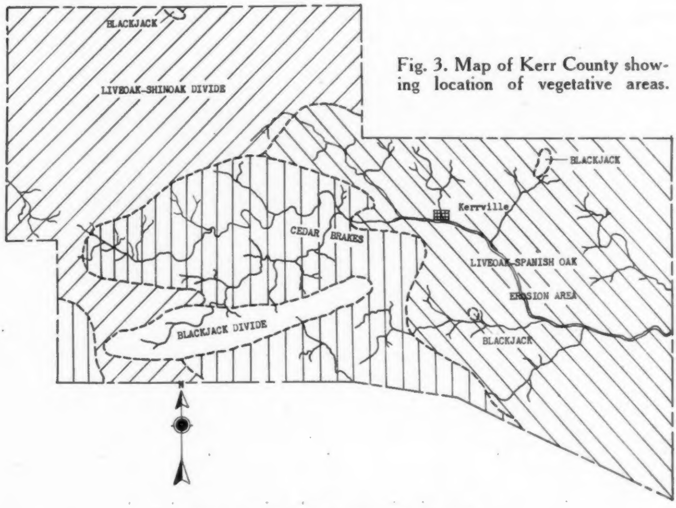

Fig. 3. Map of Kerr County showing location of vegetative areas.

The Liveoak-Shinoak Divide

This area, located on the main divide, covers approximately 248,567 acres, and consists of six communities. The occurrence of little bluestem and sideoats grama in protecting clumps of prickly pear and shinoak indicates that stages 1 and 2 in succession would exist if grazing pressure were reduced, though they are not found at the present time.

a. The Liveoak-Curly Mesquite Community

Ranges on the divide stocked at approximately 40 animal units to the section, including both livestock and deer, are of this community. Liveoak and curly mesquite grass are conspicuously dominant; sideoats grama and speargrass are also present to a considerable degree. Structurally the vegetation varies from clumps of liveoak set in broad savannas to open woodlands, the liveoak nearly always being of sprout growth form. The community is always found on the deeper soils that occur at the lower elevations of the divide and on the long, gentle slopes; it never occurs on the thin soils at higher elevations where it is replaced by shinoak savannas.

The large grass valleys of the plateau are included with this community. In such habitats the soil is deeper than on other parts of the divide and moisture conditions are more favorable. Consequently, the liveoaks attain a somewhat greater size than over most of the divide. Characteristic of these valleys is arboreal mesquite, owing its presence, among other factors, to the deep soil.

Relative importance and distributional relations of the various species are shown by the data presented in Table 1. The purpose of this and similar tables is to characterize the vegetation. Each of the grass communities is correlated with a specific grazing pressure, and should serve as a standard of comparison and a basis for management.

Fig. 4. Divide country between the drainage of the Guadalupe and Llano rivers. The trees are shinoak. (Photograph by Walter P. Taylor. Courtesy Texas Cooperative Wildlife Research Unit.)

The method adopted in presenting the tabular data is that of Egler (1940) in which the species of the community are characterized by two features which are designated as "presence" and "coverage-when-present." Presence as defined by Braun-Blanquet (1932) refers to the more or less persistent occurrence of a species in all of the stands of a particular plant community. All stands (quadrats) in the present investigation referring to presence were about 5 acres in extent. For each quadrat a complete floristic list was made; the species were then assembled in the proper presence class. A species occurring in 25 out of 50 stands, for example, was placed in the 50 percent presence class. Five percentage classes of presence are recognized: 90, 70, 50, 30, and 10 percent.

Coverage-when-present, as used by Egler (*op. cit.*), expresses the relative coverage of a given species, and is independent of its degree of presence, its abundance (number of individuals), and density (average number of individuals per unit area). Using this concept, greater precision is attained in estimating the amount of available forage for livestock and deer than in the application of abundance or density measurements alone, since it is the actual crown coverage of species that determines the amount of forage. Four coverage classes are recognized: (1) between 100 and 66 percent; (2) between 66 and 33 percent; (3) between 33 and 1 percent; and between 1 and 0 percent, the last category serving to designate certain species that are typically low in

abundance. The size of the stands used for expressions of coverage is different from that uniformly adopted for presence, and also differs for arborescent and ground vegetation. For trees and shrubs the figures for coverage-when-present refer to stands of 1/4-acre; for grasses and forbs the figures refer to stands of 100-square-meters. The purpose of using two sizes of quadrats for coverage data is to secure a maximum of distribution of species among the coverage classes. A smaller quadrat would place a majority of species in the higher coverage classes; a larger quadrat would place them all in the lower classes.

The data presented in Table 1 include range lands varying in grazing pressure from 58 to 70 animal units to the section of 640 acres. The high presence and coverage of *Evax multicaulis, E. prolifera, Aristida wrightii,* skullcap (*Scutellaria drummondii*), and hairy triodia indicate a definite retrogressive trend toward a community lower in the scale of succession. This evidence is supported by the opinion of ranchmen who claim that the amount of curly mesquite is gradually decreasing. The rate of decrease is quite slow, though still definite, at 58 animal units per section; and it is believed that not over 50 animal units (including both deer and livestock) should be placed on a section if the community is to be maintained.

Although this is the third stage in retrogressive succession, it is probably the most economical stage for livestock and deer production on the divide, assuming that the range is maintained under the proper carrying capacity. The community is wide-spread and covers an estimated 30 percent of the divide; it would occupy more territory if grazing pressure were reduced.

TABLE 1.—Presence and coverage-when-present of the species of the Liveoak-Curly Mesquite Community.

	Coverage			
	100–66 Percent	66–33 Percent	33–1 Percent	1–0 Percent
Presence of 90 percent:				
Grasses and forbs	100			
Hilaria belangeri	80	15	5	
Quercus virginiana	10	70	20	
Aristida wrightii	5	40	55	
Stipa leucotricha	5	25	70	
Browse		40	60	
Evax multicaulis		15	85	
Triodia pilosa		15	85	
Evax prolifera		10	90	
Croton monanthogynus			100	
Smilax bona-nox			100	
Tragia ramosa			100	
Scutellaria drummondii			75	25
Presence of 70 percent:				
Panicum hallii		20	80	
Opuntia lindheimeri		15	85	
Quercus breviloba		15	85	
Juniperus ashei		10	90	
Salvia farinacea		10	90	
Yucca constricta		10	90	
Berberis trifoliata			100	
Cassia roemeriana			100	

	Coverage Percent 100–66	Percent 66–33	Percent 33–1	Percent 1–0
Plantago rhodosperma			95	5
Schedonnardus paniculatus			95	5
Presence of 50 percent:				
Bouteloua curtipendula		15	85	
Aristida longiseta var. *rariflora*		10	90	
Aristida glauca		5	95	
Acacia sp.			100	
Celtis reticulata			100	
Cyperus sp.			100	
Yucca rupicola			100	
Lepidium virginicum var. *pusillum*			95	5
Euphorbia serpens			90	10
Hedeoma reverchoni			80	20
Oxalis stricta			80	20
Sida procumbens			70	30
Daucus pusillus				100
Presence of 30 percent:				
Bouteloua rigidiseta		15	85	
Aristida purpurea		5	95	
Andropogon saccharoides			100	
Andropogon scoparius var. *neomexicanus*			100	
Bouteloua hirsuta			100	
Cercis occidentalis			100	
Elymus canadensis var. *brachystachys*			100	
Forestiera neomexicana			100	
Parthenocissus heptaphylla			100	
Stillingia texana			100	
Lespedeza prairea			95	5
Verbena bipinnatifida			95	5
Bourdonia bellidifolia			90	10
Sabbatia campestris			65	35
Galium virgatum				100
Verbena plicata				100
Presence of 10 percent:				
Bumelia texana			100	
Nolina lindheimeriana			100	
Oenothera serrulata var. *drummondii*			100	
Panicum obtusum			100	
Paspalum sp.			100	
Prosopis juliflora var. *glandulosa*			100	
Prunus rivularis			100	
Quercus stellata			100	
Sophora affinis			100	
Rhus toxicodendron			100	
Chloris verticillata			90	10
Eragrostis capillaris			85	15
Cirsium sp.			80	20
Diospyros texana			80	20
Panicum sp.			75	25
Hedeoma drummondii			75	25
Acacia roemeriana			40	60
Rhus trilobata			40	60
Sporobolus asper var. *hookeri*			20	80
Portulaca retusa			15	85
Eriochloa sericea			5	95
Sida rhombifolia			5	95
Amaranthus berlandieri				100

	Coverage 100–66 Percent	66–33 Percent	33–1 Percent	1–0 Percent
Amaranthus sp.				100
Aphanostephus humulis				100
Calliandra eriophylla				100
Eriogonum longifolium				100
Euphorbia sp.				100
Leptoloma cognatum				100
Limnodea arkansana				100
Phyllanthus polygonoides				100
Polanisia trachysperma				100
Portulaca lanceolata				100
Viburnum rufidulum				100
Xanthoxylum fagara				100
Zexmenia hispida				100

b. The Liveoak-Three-awn Community

Much of the ground vegetation of the liveoak communities is in the three-awn grass stage of succession, doubtless because of the usual practice of overstocking at rates of 90 to 100 or more animal units of livestock alone (excluding deer) per section. Table 2 was constructed from quadrats taken in pastures stocked at these rates. The dominants include red three-awn (*Aristida longiseta* var. *rariflora*), *Aristida wrightii*, Texas grama, hairy triodia; subdominants include such forbs as pepper grass, yellow wood sorrel (*Oxalis stricta*), plantain, dwarf fleabane (*Erigeron divarticatus*), *Evax multicaulis*, *E. prolifera*, and nettle (*Tragia ramosa*). Curly mesquite grass occurs in scattered patches, usually where grazing is lighter. Andropogons and gramas are found where oak brush, prickly pear, or yucca provide protection from grazing. The low presence and coverage of browse species such as green brier (*Smilax bona-nox*), ill-scented sumac (*Rhus trilobata*), *Forestiera neomexicana*, and pink mimosa (*Mimosa fragrans*) is a result of heavy browsing pressure. Fewer grasses and more forbs are found in this community as compared with the

Fig. 5. Shinnery, live oak, and sumac with conspicuous goat line. Highway 41 near YO Ranch, Kerr County, Texas. (Photograph by Walter P. Taylor. Courtesy Texas Cooperative Wildlife Research Unit.)

Liveoak-Curly Mesquite Community, indicating the trend toward the forb stage of succession.

In the present seral stage, liveoak is heavily overbrowsed; seedlings and root suckers are destroyed. The total available browse is extremely scarce. If overbrowsing is continued, liveoak, as well as other browse species, ultimately will probably be completely eliminated. In view of similar overbrowsing conditions in England and other countries (Townsend, 1928), it seems likely that continued overstocking will gradually destroy the arborescent vegetation by preventing reproduction. The result would be as in England where once forested lands are now grasslands. Reducing the stock in this community to 40 or less animal units per section should permit liveoak reproduction and advancement from the three-awn stage toward the curly mesquite or grama stage.

TABLE 2.—Presence and coverage-when-present of the species of the Liveoak—Three-awn Community.

Presence of 90 percent:				
Forbs and grasses	80	15	5	
Quercus virginiana	5	70	25	
Aristida wrightii	10	10	80	
Aristida longiseta var. *rariflora*	10	10	80	
Bouteloua rigidiseta		10	90	
Triodia pilosa		10	90	
Juniperus ashei			100	
Lepidium virginicum var. *pusillum*			100	
Limnodea arkansana			100	
Opuntia lindheimeri			100	
Plantago rhodosperma			100	
Quercus breviloba			100	
Erigeron divarticatus			100	
Browse			90	10
Evax multicaulis			90	10
Schedonnardus paniculatus			90	10
Oxalis stricta			80	20
Scutellaria drummondii			80	20
Stipa leucotricha			80	20
Tragia ramosa			20	80
Galium virgatum				100
Presence of 70 percent:				
Hilaria belangeri		25	75	
Panicum hallii			100	
Euphorbia serpens			90	10
Presence of 50 percent:				
Marrubium vulgare			100	
Paronychia lindheimeri			100	
Aristida glauca			100	
Bouteloua curtipendula			75	25
Andropogon saccharoides			50	50
Andropogon scoparius var. *neomexicanus*			50	50
Cyperus sp.			20	80
Sida procumbens				100
Presence of 30 percent:				
Berberis trifoliata			100	
Eragrostis lugens			100	
Opuntia sp.			100	
Quercus marylandica			100	

	Coverage 100–66 Percent	66–33 Percent	33–1 Percent	1–0 Percent
Stillingia texana			100	
Vitis sp.			100	
Desmodium wrightii			100	
Salviastrum texanum			100	
Zexmenia hispida			100	
Croton monanthogynus			90	10
Lespedeza prairea			80	20
Sabbatia campestris			75	25
Smilax bona-nox			10	90
Daucus pusillus				100
Elymus canadensis var. *brachystachys*				100
Hedeoma drummondii				100
Phyllanthus polygonoides				100
Presence of 10 percent:				
Actinea linearifolia			100	
Bouteloua gracilis			100	
Brazoria scutellarioides			100	
Cassia roemeriana			100	
Celtis reticulata			100	
Centaurium calycosum			100	
Cercis occidentalis			100	
Cirsium sp.			100	
Convolvulus hermannioides			100	
Datura stramonium			100	
Euphorbia barbellata			100	
Parthenocissus heptaphylla			100	
Psoralea linearifolia			100	
Quercus stellata			100	
Rhus lanceolata			100	
Rhus toxicodendron			100	
Solanum rostratum			100	
Allium drummondii				100
Amaranthus berlandieri				100
Amaranthus retroflexus				100
Aphanostephus humilis				100
Bouteloua trifida				100
Dalea aurea				100
Eurytaenia texana				100
Forestiera neomexicana				100
Hedeoma reverchoni				100
Helenium elegans				100
Houstonia negricans				100
Juncus sp.				100
Krameria secundiflora				100
Lithospermum incisum				100
Lythrum lanceolatum				100
Melampodium leucanthum				100
Mimosa borealis				100
Mimosa fragrans				100
Mirabilis nyctaginea				100
Panicum sp.				100
Plantago helleri				100
Rhus trilobata				100
Sida rhombifolia				100
Specularia coloradoensis				100
Spermolepis inermis				100

c. The Liveoak-Forb Community

This community represents only a small part of Kerr County, although strong trends toward this stage in succession are found on many ranches. In this seral stage a few grasses, such as red three-awn, purple three-awn (*Aristida purpurea*), *Aristida wrightii,* Reverchon three-awn (*Aristida glauca*), hairy triodia, *Limnodea arkansana,* and Texas grama, still persist; but these are dominated by forbs, including *Evax multicaulis, E. prolifera,* mealy sage, pepper grass, plantain, dwarf fleabane, skullcap, nettle, hoarhound, *Cassia roemeriana,* and *Euphorbia serpens.* The species list of this community includes the forbs listed in Table 2, with the addition of those presented in Table 3.

TABLE 3.—Forbs found in the Liveoak-Forb Community in addition to the forbs listed in Table 1.

Astragalus macilentus	*Monarda citriodora*
Callirrhoe pedata	*Nama jamaicense*
Corydalis montana	*Oenothera serrulata* var. *drummondii*
Dacosma laciniata	*Petalostemum purpureum*
Engelmannia pinnatifida	*Polygala alba*
Gaillardia pulchella	*Psoralea linearifolia*
Gaillardia suavis	*Rudbeckia bicolor*
Gilia rigidula var. *acerosa*	*Salvia reflexa*
Heliotropium tenellum	*Spermolepis echinatus*
Houstonia minima	*Taraxacum palustre* var. *vulgare*
Hymenopappus tenuifolius	*Thelesperma simplicifolium*
Linum rupestre	*Thelesperma trifidum*
Lupinus texensis	

d. The Shinoak-Curly Mesquite Community

Found on thin soils at the higher elevations, this community covers approximately 20 percent of the divide country. It also occurs to a limited extent on summits in the eastern part of Kerr County. Stocking records of ranchmen show that this type of vegetation can be maintained with about 40 animal units per section including deer as well as livestock. When stocking is heavier than 40 animal units per section, the trend is toward the three-awn grass seral stage, although when heavily overstocked the community may be replaced directly by unpalatable forbs and bare ground.

Shinoak and curly mesquite are conspicuously dominant, while three-awn grasses, hairy triodia, and various forbs such as *Cassia roemeriana,* Mexican tea, mealy sage, *Evax multicaulis, E. prolifera, Euphorbia serpens,* and skullcap are subdominants on small areas where the soil is exceptionally thin and rocky. Table 2 includes practically the same species as those found in the present community. The ground vegetation is essentially the same in both the Liveoak-Curly Mesquite and Shinoak-Curly Mesquite Communities.

When properly utilized, shinoak usually covers from 33 to 66 percent of the land. Light or moderate browsing causes shinoak to propagate extensively by root suckers, and to such an extent that more land is sometimes covered by this species than is economically desirable; but even stocking at the rate of 65 animal units per section, when 25 percent of this total is allotted to goats and 20 percent to white-tailed deer, produces a noticeable decline in the amount

of shinoak browse. Of course, reducing the percentage of browsing animals may hold the shinoak browse at the desirable coverage. It is undesirable to have either too much or too little shinoak browse; management practices should adjust the total stocking and the percentages of browsing animals to maintain the available browse at the most economical coverage.

During the spring, summer, and fall, deer and goats show a definite preference for this community, doubtless because of the abundance of browse. Goats, sheep, and deer usually bed in this type of vegetation, since it is correlated with the higher elevations where comparatively high wind velocities maintain lower temperatures and keep the area more or less free from flies.

Perhaps the most important management problem is in adjustment to the range of the different classes of livestock in the proper proportions. Goats and deer show a strong predilection for browse; and when goats exceed 16 percent of the total animal units, while deer exceed 8 percent, shinoak becomes overbrowsed (see Table 12). Overstocking the community at 60 or more animal units per section results in retrogression from the curly mesquite grass stage to the three-awn grasses and forbs.

e. The Shinoak-Three-awn Community

Quadrats taken in the present community in pastures stocked at 78 to 100 or more livestock units per section indicate that the ground vegetation is essentially the same as that of the Liveoak-Three-awn Community. The principal difference between the two communities is that shinoak replaces liveoak as the dominant arborescent species and that several forbs, though subdominants, characterize the ground vegetation of the Shinoak-Three-awn Community. The most conspicuous of these forbs are *Paronychia lindheimeri,* lemon-scented pectis (*Pectis angustifolia*), and alfilaria (*Erodium cicutarium*); apparently they are restricted to the thin soils on which the Shinoak-Three-awn Community is found. Other species found in the present community in addition to those listed in Table 2 are presented in Table 4.

TABLE 4.—Species found in the Shinoak—Three-awn Community in addition to those listed in Table 2.

Abutilon incanum	*Gossypianthus lanuginosus*
Acacia greggii	*Hedeoma accinoides*
Actinea odorata	*Hordeum pusillum*
Amaranthus graecizans	*Panicum filipes*
Artemisia gnaphalodes	*Parietaria floridana*
Bourdonia effusa	*Passiflora lutes*
Cenchrus pauciflorus	*Passiflora tenuiloba*
Cercocarpus argenteus	*Pectis angustifolia*
Cirsium austrinum	*Polygala lindheimeri*
Conobea multifida	*Portulaca parvula*
Cyperus uniflorus	*Prunus eximia*
Dyschoriste linearis	*Rhynchosia texana* var. *angustifolia*
Eragrostis curtipedicellata	*Sedum nuttallianum*
Eragrostis poaeoides	*Silphium albiflorum*
Erodium circutarium	*Tribulus terrestris*
Euphorbia missurica var. *intermedia*	*Symphoricarpos orbiculatus*
Franseria confertiflora	*Tetragonotheca repanda*

When stocking pressures are near 100 animal units per section the many forbs found associated with the three-awn ground vegetation tend to become dominant. Although these forbs provide valuable forage, they cover only a relatively small part of the ground, and, except in spring, actually provide little of the available food in the pastures. Moreover, many of these forbs, such as *Evax multicaulis*, *E. prolifera*, nettle, *Paronychia lindheimeri*, and lemon-scented pectis are more or less unpalatable to livestock.

Since the Shinoak-Three-awn Community is found on thin, rocky soils at the higher elevations (summits and slopes) on the divide and on summits in eastern Kerr County, it is subject to severe ecological conditions, including high winds, drought, heavy erosion, and shallow soils. Under these conditions the community is susceptible to injury with stocking pressures that are suitable for the liveoak communities that occur in the better habitats. Although it is practically impossible to control the distribution of stock on large ranches where shinoak and liveoak communities are interspersed, it is desirable to stock pastures or ranches dominated by shinoak at not more than 40 animal units per section.

f. The Shinoak-Forb Community

Although the species found in this community are generally the same as those found in the Liveoak-Forb Community, dominance differs considerably, shinoak, *Paronychia lindheimeri*, lemon-scented pectis, alfilaria, prickly pear, and yucca being dominant in the present community.

Under the heavy stocking pressures of 100 or more animal units per section that ordinarily accompany this type of vegetation, as well as the Liveoak-Forb Community, most of the palatable forbs are scarce and scattered, leaving the relatively unpalatable species dominant. This community is of little value to livestock or deer, and is subject to severe soil erosion. If overgrazing is continued, bare ground becomes dominant, erosion is unchecked, and the land deteriorates greatly. It is preferable to defer grazing on pastures

Fig. 6. Bare ground stage of succession caused by overgrazing. The final stage of depletion, Kerr County, Texas. (Photograph by Walter P. Taylor. Courtesy Texas Cooperative Wildlife Research Unit.)

in this community until sufficient recovery has been made to insure progression toward the higher stages in succession.

THE BLACKJACK DIVIDE

According to Hill and Vaughan (1897), some beds of the Edwards geological formation have admixtures of silica; apparently the blackjack communities are correlated with these deposits. The rocks and soils are reddish and yellow-brown in color, indicating high percentages of iron derivatives. The largest and most typical blackjack area comprises about 32,000 acres in south-central Kerr County on the narrow divide between the Medina and Guadalupe watershed. Westward this type fans out into the main divide where it meets the Liveoak-Shinoak area. While as stated, blackjack and its associated species nearly always occur on silica ridges, they are also occasionally found on deep soils at lower elevations. Besides the main area on the Medina-Guadalupe divide, small patches of blackjack communities exist as indicated in Fig. 3, and doubtless there are others.

a. The Blackjack-Little Bluestem Community

Less than one percent of the county is represented by this community. It occurs where pastures are lightly stocked or in unfrequented portions of large pastures. Table 5 is based on quadrats taken in a 600-acre pasture stocked with about 50 units of cattle per section during the spring, summer, and fall; and an additional 30 units of sheep during the winter. During the winter, however, the cattle receive considerable supplementary feed, thus relieving the range of much grazing pressure. Doubtless, conservative grazing is responsible for the advanced successional stage and excellent condition of the vegetation. It is believed that the community represented by Table 5 is near the climax for this area and that the abundance of species such as *Aristida wrightii*, prairie three-awn (*Aristida oligantha*), and *Panicum oligosanthes* is caused by local concentrations of stock. When the area has more fully recovered from the previous heavy stocking, these species will be replaced by andropogons and grama grasses. Other pastures on the same ranch, grazed by sheep and cattle, are more heavily stocked and are dominated by three-awn grasses and speargrass.

In the present community blackjack, post oak, little bluestem grass, silver beardgrass, sideoats grama, and speargrass are the dominant species. Blackjack and post oak may occur together in stands dense enough to exclude most of the ground vegetation, but usually the grasses and forbs cover 66 to 100 percent of the ground. Browse is relatively scarce in this community, partly because of the previous heavy goat browsing and partly because of the physiognomy of the vegetation. Blackjack and post oak trees grow to a height of 15 to 20 feet, often with a diameter (breast-height) of 16 to 20 inches, and provide little browse. Most of the existing browse is composed of liveoak that occurs in small, scattered stands throughout the community. According to the ranchman, ill-scented sumac, wild plum (*Prunus rivularis*), and dewberry (*Rubus trivialis*) provided considerable browse before the land was overbrowsed by goats. At the present time about 46 deer are found per section;

TABLE 5.—Presence and coverage-when-present of species of the Blackjack-Little Bluestem Community.

	Coverage 100–66 Percent	66–33 Percent	33–1 Percent	1–0 Percent
Presence of 90 percent:				
Grasses and forbs	90	5	5	
Quercus marylandica	50	30	20	
Andropogon scoparius var. *neomexicanus*	20	70	10	
Stipa leucotricha	5	15	80	
Andropogon saccharoides		20	80	
Bouteloua curtipendula		20	80	
Bouteloua hirsuta		20	80	
Browse		10	90	
Quercus stellata		10	90	
Quercus virginiana		10	90	
Eragrostis lugens		5	95	
Aristida wrightii			100	
Cyperus sp.			100	
Opuntia lindheimeri			100	
Panicum hallii			100	
Stillingia texana			100	
Zexmenia hispida			100	
Croton monanthogynus			90	10
Euphorbia serpens			90	10
Smilax bona-nox			90	10
Oxalis stricta			80	20
Lespedeza prairea			50	50
Tragia ramosa				100
Presence of 70 percent:				
Actinea linearifolia			100	
Aristida oligantha			100	
Muhlenbergia lindheimeri			100	
Panicum oligosanthes			100	
Ruellia ciliosa			100	
Sporobolus asper var. *hookeri*			100	
Vitis sp.			100	
Desmanthus acuminatus			70	30
Juniperus ashei			25	75
Hedeoma reverchoni			20	80
Evax multicaulis			10	90
Evax prolifera			10	90
Daucus pusillus				100
Galium virgatum				100
Lepidium virginicum var. *pusillum*				100
Phyllanthus polygonoides				100
Sida procumbens				100
Spermolepis inermis				100
Presence of 50 percent:				
Aristida glauca			100	
Erigeron divarticatus			100	
Passiflora lutea var. *glabriflora*			100	
Quercus laceyi			100	
Rhus lanceolata			100	
Tragia nigricans			100	
Yucca rupicola			100	
Paronychia lindheimeri			100	
Cenchrus pauciflorus			100	
Plantago rhodosperma			10	90
Scutellaria drummondii			10	90

	Coverage			
	100–66 Percent	66–33 Percent	33–1 Percent	1–0 Percent
Presence of 30 percent:				
Aristida longiseta var. *rariflora*			100	
Elymus canadensis var. *brachystachys*			100	
Eragrostis poaeoides			100	
Mirabilis nyctaginea				100
Verbena plicata				100
Sabbatia campestris				100
Presence of 10 percent:				
Asclepias verticillata			100	
Celtis reticulata			100	
Cyperus elegans			100	
Cyperus schweinitzii			100	
Digitaria sanguinalis			100	
Juglans rupestris			100	
Leptochloa dubia			100	
Lespedeza virginica			100	
Muhlenbergia lindheimeri			100	
Parthenocissus heptaphylla			100	
Schedonnardus paniculatus			100	
Verbena bipinnatifida			100	
Abutilon incanum				100
Calliandra eriophylla				100
Conobea multifida				100
Hedeoma acinoides				100
Helenium badium				100
Heliotropium tenellum				100
Notholaena sinuata				100
Oxalis drummondii				100
Scleria pauciflora				100
Sida rhombifolia				100
Triodia albescens				100
Triodia pilosa				100
Xanthoxylum fagara				100

but it is encouraging to note that, even with this large number of deer, valuable browse species such as green brier and *Zexmenia hispida* are increasing in abundance. No individuals of wild plum, ill-scented sumac, *Forestiera neomexicana*, or dewberry were found in this area, indicating, perhaps, that these species have been eliminated from the community.

The fact that conservative grazing on one 600-acre pasture of a 6000-acre ranch is responsible for the dominance of little bluestem and sideoats grama, while the other pastures are characterized by three-awn grasses and speargrass, seems to demonstrate that the more valuable grasses can be maintained under lighter grazing. Probably 50 animal units (including deer, but preferably excluding goats) per section can be sustained on pastures in the Blackjack-Little Bluestem Community.

b. The Blackjack-Grama Community

The ground vegetation of this community occupies a position below that of the Blackjack-Little Bluestem Community. During the present investigation, this community was found only in small areas scattered throughout the Blackjack-Little Bluestem Community in the pasture referred to above. Probably most of the area was covered by this seral stage during the process of vegeta-

tive recovery in the pasture. Blackjack, post oak, sideoats grama, hairy grama, *Eragrostis lugens*, and speargrass are the dominants, while blue grama and Texas grama occur in small quantities. Most of the forbs listed in Table 5 are also found, some of them, such as yellow wood sorrel, *Zexmenia hispida, Stillingia texana,* and bush clover (*Lespedeza virginica*), being conspicuous subdominants. Pastures in this seral stage would appear quite similar to those of the climax, except that sideoats grama and hairy grama, rather than little bluestem, would be dominant. When subject to grazing, the Blackjack-Little Bluestem Community usually shows a strong transition toward the present community.

c. The Blackjack-Buffalo Grass Community

Open blackjack areas that are sufficiently moist are likely to be of this community. A considerable part of the small blackjack area in eastern Kerr County (Fig. 3), where numerous small permanent streams are found, is dominated by buffalo grass. Where arborescent vegetation exceeds about 50 percent of the ground coverage, speargrass and three-awn grasses are dominant.

The physiological requirements of buffalo grass indicate that it is above curly mesquite grass in succession, but it does not necessarily follow that the former always succeeds the latter. Mixtures of buffalo grass and curly mesquite were found in the eastern part of the county, where succession probably included stages dominated by each species. The usual course of succession on the Medina-Guadalupe divide and on the main divide is direct from the curly mesquite stage to the grama or little bluestem stage, since these regions are apparently too arid for the successful establishment of buffalo grass.

d. The Blackjack-Curly Mesquite Community

Found only to a limited extent, this community occurs where large openings, about three acres or more in size, provide sufficient sunlight for the growth of curly mesquite grass. Apparently this grass is intolerant to the shade and soil conditions found where blackjack and post oak cover 33 to 100 percent of the land. Pastures in which curly mesquite dominates openings are of the speargrass type of ground vegetation.

e. The Blackjack-Speargrass Community

Most of the blackjack area is of this community. Blackjack, speargrass, red three-awn, *Aristida wrightii,* and curly mesquite are the dominants. Live-oak occurs in small, pure stands scattered throughout the community, while post oak is found interspersed with blackjack. Only in openings three to five acres or larger is curly mesquite dominant. Most of the ground vegetation is influenced by light and soil conditions that exist beneath the canopy of blackjack and post oak. Speargrass appears to be highly tolerant to these conditions. Two other factors favor speargrass: (1), its relatively low palatability; and (2), its position as a climax species in succession. Although speargrass provides considerable green forage during the winter, the long, needle-like awns that mature in the spring are particularly annoying to sheep. The awns penetrate the eyes, nose, and the flesh behind the neck, causing serious pathological effects. Some ranchmen are of the opinion that heavy thinnings or clearcutting

blackjack and post oak followed by overgrazing with sheep will provide a suitable habitat for curly mesquite and reduce competition from speargrass to the extent that curly mesquite can become established. This treatment may injure the vegetation and soil more than it improves the grazing conditions; further study of the problem is needed before definite recommendations can be made.

Since this community has been found in pastures stocked with 80 to 90 animal units of livestock (excluding deer) per section, the indication is that speargrass can withstand considerable grazing pressure.

TABLE 6.—Presence and coverage-when-present of species of the Blackjack-Speargrass Community.

	Coverage 100–66 Percent	66–33 Percent	33–1 Percent	1–0 Percent
Presence of 90 percent:				
Grasses and forbs	100			
Stipa leucotricha	20	60	20	
Quercus marylandica	20	50	30	
Hilaria belangeri	5	15	80	
Aristida longiseta var. *rariflora*	5	10	85	
Aristida wrightii		20	80	
Quercus virginiana		5	95	
Browse		5	95	
Opuntia lindheimeri			100	
Quercus stellata			100	
Bouteloua curtipendula			95	5
Evax multicaulis			90	10
Evax prolifera			90	10
Tragia ramosa				100
Presence of 70 percent:				
Bouteloua rigidiseta			100	
Erigeron divarticatus			100	
Triodia pilosa			100	
Hedeoma reverchoni			10	90
Oxalis stricta			10	90
Scutellaria drummondii			5	95
Sida procumbens			5	95
Smilax bona-nox			5	95
Presence of 50 percent:				
Aristida glauca			100	
Cyperus sp.			100	
Panicum hallii			100	
Stillingia texana			100	
Bouteloua hirsuta			95	5
Schedonnardus paniculatus			95	5
Lepidium virginicum var. *pusillum*			5	95
Euphorbia serpens				100
Presence of 30 percent:				
Andropogon scoparius var. *neomexicanus*			100	
Eragrostis lugens			100	
Croton monanthogynus			90	10
Juniperus ashei			90	10
Limnodea arkansana			50	50
Desmanthus acuminatus				100
Plantago rhodosperma				100
Galium virgatum				100

	Coverage 100–66 Percent	66–33 Percent	33–1 Percent	1–0 Percent
Presence of 10 percent:				
Abutilon incanum			100	
Acacia roemeriana			100	
Actinea sp.			100	
Andropogon saccharoides			100	
Aristida purpurea			100	
Aristida oligantha			100	
Bouteloua gracilis			100	
Bourdonia bellidifolia			100	
Buchloe dactyloides			100	
Cenchrus pauciflorus			100	
Datura stramonium			100	
Juglans rupestris			100	
Marrubium vulgare			100	
Muhlenbergia lindheimeri			100	
Panicum oligosanthes			100	
Parthenocissus heptaphylla			100	
Quercus breviloba			100	
Quercus texana			100	
Rhus lanceolata			100	
Rhus toxicodendron			100	
Verbena bipinnatifida			100	
Verbena plicata			100	
Vitis sp.			100	
Lespedeza prairea			60	40
Amaranthus berlandieri				100
Amaranthus retusa				100
Aphanostephus humilus				100
Euphorbia supina				100
Cyperus schweinitzii				100
Dalea aurea				100
Helenium badium				100
Lespedeza virginica				100
Linum multicaule				100
Melica mutica				100
Nepeta cataria				100
Paspalum sp.				100
Sabbatia campestris				100
Sida rhombifolia				100
Specularia coloradoensis				100
Spermolepis inermis				100

THE LIVEOAK-SPANISH OAK EROSION AREA

Approximately the eastern third of Kerr County is characterized by hills and valleys. The slopes, as well as the summits from which the hard Edwards limestone has been eroded, exposing the soft Walnut formation, are covered with Spanish oak; while the lower slopes and valleys are dominated by liveoak. The erosion area comprises about 269,769 acres, half of which, it is estimated, consists of Spanish oak communities. Liveoak and shinoak communities, farm lands, and riparian vegetation constitute the remaining area.

The highest summits are capped with Edwards limestone, and support liveoak and shinoak communities. In local areas cedar may be found invading valleys, slopes, or summits.

a. The Liveoak-Little Bluestem Community

The Kerrville State Park, three miles southeast of Kerrville, and a private estate, free from grazing, two miles south of Kerrville, are the only areas in which this community was found. Grazing on the state park had always been light; it was prohibited in 1940. At the present time, although some three-awn grasses and forbs still persist, little bluestem dominates the park. Liveoak, little bluestem, silver beardgrass, and speargrass dominate the present community.

It is believed that pracically all of the ground vegetation in Kerr County would be dominated by little bluestem and its associated species if grazing were light enough. But this type of vegetation may not be the most economical .Evidence from stocking records shows that grazing lightly enough to produce climax ground cover is not as profitable as heavier stocking that may produce a grama stage or curly mesquite stage in succession. Though, as Cory (1927) indicates, cattle do best in climax vegetation, sheep prefer an abundance of forbs, as found in the second and third seral stages. The true climax vegetation is relatively free from forbs. The multiple use of livestock on the present Kerr County ranges doubtless yields more profit than could be realized from cattle alone on climax ranges, provided the dangers are avoided of economic loss through overstocking.

b. The Liveoak-Buffalo Grass Community

On deep soils with sufficient moisture, usually found in the main valleys such as Turtle Creek and the Guadalupe, the Liveoak-Buffalo Grass Community occurs to some extent. Buffalo grass is highly palatable to all types of livestock; it is estimated that this grass cannot withstand grazing pressures greater than 50 animal units (including deer) per section. When grazing is overheavy, the buffalo grass is soon replaced by three-awn grasses.

Liveoak and buffalo grass are conspicuous and dominant in this community; sideoats grama and red three-awn are found in scattered patches; and red grama (*Bouteloua trifida*), Texas grama, and *Cyperus elegans*, as well as several forbs such as *Sida rhombifolia*, skullcap, and plantain, are interspersed with the dominants.

Browse is usually extremely scarce in the present community, but under light or moderate browsing, even an overabundance of liveoak browse may be produced. Moreover, browse species such as *Forestiera neomexicana*, ill-scented sumac, and green brier are not eliminated when browsing pressure by livestock is not overheavy.

The community requires deep soil and flat topography; even on small slopes buffalo grass is replaced by three-awn grasses and hairy triodia.

c. The Liveoak-Muhlenbergia Community

This community is typical of the lower lying broad draws or swales of eastern Kerr County. The data in Table 7 indicate that *Muhlenbergia utilis*, *M. lindheimeri*, wedgeleaf fog-fruit (*Lippia nudiflora*), and liveoak are dominant. Speargrass, Texas grama, field sandbur (*Cenchrus pauciflorus*), *Stil-*

lingia texana, Paspalum hartwegiana, knotroot bristlegrass (*Setaria geniculata*), dewberry, and windmill grass (*Chloris verticillata*) also characterize the community. Occasionally red mulberry (*Morus rubra*), buttonbush (*Cephalanthus occidentalis*), and sycamore are found.

When the community is grazed, grasses such as little bluestem, sideoats grama, and Texas grama are clipped short between the bunches of Lindheimer muhlenbergia, the latter being comparatively low in palatability. The reduced competition from these species, as well as the caliche soil, permits the successful establishment of less valuable species, such as field sandbur, windmill grass, and wedgeleaf fog-fruit. Because of the abundance of forbs, the low palatability of the muhlenbergias, and the small amount of available browse, this type of vegetation is only of limited value to livestock and deer.

TABLE 7.—Presence and coverage-when-present of species of the Live-oak-Muhlenbergia Community.

	Coverage			
	100–66 Percent	66–33 Percent	33–1 Percent	1–0 Percent
Presence of 90 percent:				
Grasses and forbs	100			
Muhlenbergia utilis	30	10	60	
Muhlenbergia lindheimeri	20	60	20	
Lippia cuneifolia		10	90	
Quercus virginiana		5	95	
Eragrostis lugens			100	
Smilax bona-nox			100	
Stipa leucotricha			100	
Bouteloua rigidiseta			100	
Browse			100	
Cenchrus pauciflorus			90	10
Cyperus sp.			80	20
Andropogon scoparius var. *neomexicanus*			75	25
Verbena bipinnatifida			70	30
Euphorbia serpens			50	50
Evax prolifera			50	50
Oxalis stricta			50	50
Evax multicaulis				100
Presence of 70 percent:				
Sporobolus asper var. *hookeri*		10	90	
Stillingia texana			100	
Zexmenia hispida			90	10
Juniperus ashei			50	50
Croton monanthogynus			35	65
Andropogon saccharoides			25	75
Lespedeza prairea				100
Sida procumbens				100
Verbena plicata				100
Presence of 50 percent:				
Aristida longiseta var. *rariflora*			100	
Aristida wrightii			100	
Berberis trifoliata			100	
Paspalum hartwegianum			100	
Setaria geniculata			80	20
Rubus trivialis			50	50
Bouteloua curtipendula			10	90
Presence of 30 percent:				

	Coverage 100–66 Percent	66–33 Percent	33–1 Percent	1–0 Percent
Chloris verticillata		5	95	
Actinea odorata			100	
Aster ericoides			100	
Aster spinosus			100	
Celtis reticulata			100	
Cephalanthus occidentalis			100	
Euphorbia missurica			100	
Morus rubra			100	
Muhlenbergia reverchoni			100	
Quercus texana			100	
Sorghastrum nutans			100	
Triodia albescens			100	
Vitis rupestris			100	
Panicum hallii			90	10
Teucrium canadense var. *virginicum*			90	10
Panicum filipes			80	20
Hedeoma reverchoni				100
Panicum capillare				100
Phyllanthus polygonoides				100
Plantago rhodosperma				100
Scutellaria drummondii				100
Presence of 10 percent:				
Ambrosia psilostachya			100	
Aphanostephus humilus			100	
Aristida glauca			100	
Aristida purpurea			100	
Asclepias marginata			100	
Chloris latisquamea			100	
Diospyros texana			100	
Opuntia lindheimeri			100	
Panicum lanuginosum var. *lindheimeri*			100	
Platanus occidentalis			100	
Rhus lanceolata			100	
Samolus parviflorus			100	
Verbascum thapsus			100	
Vitis berlandieri			100	
Yucca rupicola			100	
Abutilon incanum				100
Amaranthus berlandieri				100
Bourdonia bellidifolia				100
Bouteloua gracilis				100
Bouteloua hirsuta				100
Buchloe dactyloides				100
Conobea multifida				100
Conyza coulteri				100
Desmanthus acuminatus				100
Echinochloa colunum				100
Euphorbia angusta				100
Indigofera tinctoria				100
Juncus sp.				100
Panicum oligosanthes				100
Parthenocissus heptaphylla				100
Polygala alba				100
Ruellia ciliosa				100
Sporobolus vagniflorus				100
Tragia ramosa				100
Triodia pilosa				100

d. The Spanish Oak-Little Bluestem Community

The discussion of the Liveoak-Little Bluestem Community applies also to this community. The principal difference is that Spanish oak replaces liveoak on slopes and low summits where the thin caliche soils occur. Little bluestem grows well on slopes. If left unburned and grazed lightly, it is perhaps the most economical grass that can be maintained. Slopes are always subject to severe erosion; and since the turf grasses, buffalo grass and curly mesquite, are not structurally fitted for this habitat, even moderate grazing may produce harmful effects on the vegetation. While it is difficult to control livestock in pastures that include valleys and slopes, it should be recognized that proper stocking for the valleys and lower slopes may be overstocking for the upper slopes, and adjustments should be made to insure proper utilization of the slopes. Though it seems logical to expect that little bluestem and grama grasses would yield greater profits, most ranches in the erosion area of Kerr County are overstocked, as conclusively shown by the abundant three-awn grasses on the slopes. Appearance of this indicator of overgrazing shows that the soil on the affected slopes is in serious danger of further erosion and possible early destruction. The turf is relatively thin and erosion is considerably accelerated over that in the grama or little bluestem seral stage. Moreover, the reduced competition from grasses encourages the invasion and establishment of cedar.

e. The Spanish Oak-Grama Community

While not actually found as a well-defined community, it is believed that the Spanish Oak-Grama Community would exist under light grazing on slopes. In studying the Spanish Oak-Three-awn Community, it was found that grama grasses, sideoats grama, blue grama, hairy grama, and Texas grama, do well on slopes. Lighter stocking than is usually employed would probably allow grama grasses to form a distinct and profitable community. Perhaps 40 to 50 animal units (including deer) per section, rather than the usual 70 to 80 or more animal units per section would permit the establishment of the grama seral stage on slopes.

f. The Spanish Oak-Three-awn Community

This is the usual community found in the Spanish oak habitat. Most of the species of this community are listed in Table 2; additions have been made in Table 8. Stocking at 70 animal units (excluding deer) per section on slopes in eastern Kerr County reduces most of the desirable grasses, leaving three-awn grasses, hairy triodia, Texas grama, and many forbs such as *Stillingia texana*, small-flowered verbena, nettle, *Zexmenia hispida*, *Sida procumbens*, Mexican tea, and *Euphorbia serpens*. Sideoats grama and *Sporobolus asper* var. *hookeri*, however, still persist in considerable quantities. Yucca and agrito (*Berberis trifoliata*) are abundant; together with sotol (*Dasylirion texanum*) and ribbon grass (*Nolina lindheimeriana*) they give the community a distinctive xeric appearance. Agrito and ribbon grass, as well as green brier, are utilized as browse by deer and goats; but browse is relatively scarce in this community. The growth form of Spanish oak is not productive of abundant

browse. Usually these trees grow to a height of 15 to 20 feet, and most of the browse is beyond the reach of deer and goats.

Occasionally Spanish oak may form a canopy dense enough to eliminate most of the ground vegetation, particularly the grasses. Except for the Spanish oak mast, practically no food is available for livestock and deer in such areas.

If stocking is continued at the present rate, seedlings and sprouts of Spanish oak and its associated trees will be unable to survive. More important, final destruction of the soil will follow, and the land will become useless.

TABLE 8.—Species found in the Spanish Oak—Three-awn Community in addition to those listed in Table 2.

Acalypha lindheimeri	*Linum rupestre*
Aesculus discolor	*Melampodium leucanthum*
Aphanostephus ramosissimus var. *helleri*	*Mirabilis comata*
Astragalus macilentus	*Muhlenbergia reverchoni*
Bourdonia effusa	*Muhlenbergia utilis*
Bouteloua hirsuta	*Nolina lindheimeriana*
Calliandra eriophylla	*Panicum reverchoni*
Callirrhoe pedata	*Petalostemum purpureum*
Carya buckleyi	*Prunus eximia*
Cenchrus pauciflorus	*Quercus texana*
Chrysactina mexicana	*Rhus virens*
Conyza coulteri	*Ruellia ciliosa*
Daucosma laciniata	*Samolus parviflorus*
Dasylirion texanum	*Sporobolus vaginiflorus*
Desmanthus acuminatus	*Tilia texana*
Diospyros texana	*Vernonia lindheimeri*
Eriogonum longifolium	*Viburnum rufidulum*
Forestiera reticulata	*Yucca rupicola*
Juglans rupestris	

THE CEDAR BRAKES

In the central and south-central portions of Kerr County, cedar comprises 80 percent or more of the arborescent vegetation. This type of vegetation, known as the cedar brakes, covers 24.3 percent of the county, or about 177,652 acres.

Fig. 7. Areas with 80 percent or more cedar are known as cedar brakes. These occupy 24 percent of the area of Kerr County, Texas. (Photograph by Walter P. Taylor. Courtesy Texas Cooperative Wildlife Research Unit.)

Although a large part of the area now designated as cedar brakes was originally covered with cedar when white man made his first appearance, much additional land has been taken over by cedar since the introduction of livestock.

a. The Cedar-Grama Community

Grama grasses, including sideoats grama, hairy grama, blue grama, red grama, and Texas grama, are found in virgin cedar communities that have been stocked lightly and in areas relieved of heavy grazing. Recovery from a three-awn seral stage to the grama stage is known to have occurred on at least one ranch in Kerr County. In this area the above grama grasses, as well as the other valuable grasses, such as curly mesquite, little bluestem, silver beardgrass, and *Sporobolus asper,* occur in abundance.

The existence of the Cedar-Grama Community indicates the possibility of stocking lightly enough to allow more valuable grasses to become established and to persist, rather than the three-awn grasses usually found dominating the ground vegetation in cedar brakes.

b. The Cedar-Three-awn Community

The three-awn grasses, Reverchon three-awn, red three-awn, and *Aristida wrightii;* Texas grama; *Cyperus* sp.; and cedar are dominant in this community. In Table 9 are presented the associated species in order of their relative significance. The ground vegetation is thin, much bare ground being exposed. Heavy stocking is responsible for the low stage in succession and for the exposed soil.

Though browse and other food is relatively scarce, deer utilize the community to a large extent in fall and winter for protection against adverse weather conditions and hunters. Censuses of deer utilizing cedar brakes made in November showed large increases over those in September. Evidence of considerable feeding on cedar berries by deer was observed.

Some cedar brakes are dense enough to exclude nearly all of the ground vegetation, including seedlings of cedar and oaks. These are usually pure stands of cedar of uniform age. It is difficult to determine what the ultimate appearance of the vegetation will be under continued elimination, by livestock and deer, of the scattered oak and cedar seedlings that do become established. The mature cedar trees will doubtless remain for many decades; and as they die, openings will probably permit more cedar seedlings to become established than the livestock and deer are able to destroy. Even in the seedling stage, cedar is quite unpalatable to deer and stock, and the seedlings are utilized only when other food is extremely scarce. It is doubtful that the oaks will replace the cedar if grazing is continued, since deer and livestock utilize practically all of the palatable young seedlings and suckers.

Many of the cedar brakes in Kerr County are being cut to provide more browse and grass for livestock. When cedar is removed, the scattered, suppressed clumps of shinoak become dominant; grasses become established soon. depending upon the rate of stocking following the cutting operations.

TABLE 9.—Presence and coverage-when-present of species of the Cedar-Three-awn Community.

	Coverage 100–66 Percent	66–33 Percent	33–1 Percent	1–0 Percent
Presence of 90 percent:				
Juniperus ashei	90	10		
Grasses and forbs	70	15	15	
Aristida glauca		50	50	
Bouteloua rigidiseta		5	95	
Aristida wrightii		5	85	10
Aristida longiseta var. *rariflora*			100	
Opuntia lindheimeri			100	
Cyperus sp.			100	
Triodia pilosa			95	5
Diospyros texana			90	10
Panicum oligosanthes			90	10
Quercus breviloba			90	10
Quercus virginiana			90	10
Browse			85	15
Euphorbia serpens			80	20
Sida procumbens			80	20
Evax prolifera			70	30
Panicum hallii			60	40
Evax multicaulis			50	50
Verbena bipinnatifida			50	50
Presence of 70 percent:				
Bouteloua hirsuta		5	95	
Stipa leucotricha		5	95	
Sporobolus asper var. *hookeri*			90	10
Verbena plicata			50	50
Smilax bona-nox				100
Presence of 50 percent:				
Aristida oligantha			100	
Berberis trifoliata			100	
Bouteloua curtipendula			100	
Eragrostis lugens			100	
Galium virgatum				100
Hedeoma reverchoni				100
Phyllanthus polygonoides				100
Yucca rupicola				100
Presence of 30 percent:				
Marrubium vulgare			100	
Muhlenbergia lindheimeri			100	
Croton monanthogynus			50	50
Celtis reticulata				100
Lespedeza virginicum				100
Presence of 10 percent:				
Arbutus texana			100	
Aristida purpurea			100	
Cercocarpos breviflorus			100	
Hilaria belangeri			100	
Muhlenbergia reverchoni			100	
Nolina lindheimeriana			100	
Verbascum thapsus			100	
Acacia roemeriana				100
Actinea linearifolia				100
Amaranthus berlandieri				100
Andropogon scoparius var. *neomexicanus*				100
Cenchrus pauciflorus				100

	Coverage 100–66 Percent	66–33 Percent	33–1 Percent	1–0 Percent
Crataegus reverchoni				100
Daucus pusillus				100
Desmanthus acuminatus				100
Krameria secundiflora				100
Hedeoma drummondii				100
Lespedeza prairea				100
Plantago rhodosperma				100
Quercus laceyi				100
Quercus marylandica				100
Quercus texana				100
Scutellaria drummondii				100
Sophora affinis				100
Spermolepis inermis				100
Zexmenia hispida				100

According to Clements and others (1941), cedar brakes occur where effective and extensive disturbance (*i.e.*, grazing) persists, and in conformity with their origin can be changed back into the proper vegetation wherever the dominants of the latter persist in sufficient quantity. He states, furthermore, that more land can be returned quickly and cheaply to grass by the conversion of such vegetation as cedar brakes than by any other method.

The Riparian Community Group

The riparian community group covers only about one percent of Kerr County; and was not given much attention during the present investigation, although these communities are of some value to livestock and deer.

a. The Spanish Oak-Draw Community

The dry washes and draws found throughout the county, on the divides as well as in the erosion area, are characterized by Spanish oak and Lacey oak. On the silicate soils of the blackjack divide and on extremely steep slopes anywhere in the county, Lacey oak occurs in greater abundance than Spanish

TABLE 10.—List of plants found in the Spanish Oak-Draw Community

Adiantum capillus-veneris
Andropogon scoparius
Aristida longiseta var. *rariflora*
Aristida wrightii
Bouteloua curtipendula
Cyperus sp.
Desmanthus acuminatus
Diospyros texana
Dryopteris normalis
Euphorbia serpens
Hedeoma reverchoni
Juglans rupestris
Juniperus ashei
Muhlenbergia reverchoni
Nolina lindheimeriana
Opuntia lindheimeri
Oxalis drummondii
Panicum oligosanthes
Pellaea atropurpurea
Prunus eximia
Quercus breviloba
Quercus laceyi
Quercus texana
Rhus toxicodendron
Sida procumbens
Smilax bona-nox
Sporobolus asper
Stillingia texana
Tilia texana
Tragia ramosa
Verbena bipinnatifida
Verbesina virginica
Vitis rupestris
Yucca rupicola
Zexmenia hispida

oak. Apparently the reduced competition from Spanish oak in these habitats permits Lacey oak to become dominant. Some of the species found in the Spanish Oak-Draw Community are listed in Table 10.

Usually much, sometimes all, of the surface of the ground is bare of vegetation; and is covered by a thick litter of oak leaves. Browse and other food are quite scarce, but the community provides considerable protection for livestock and deer from cold north winds during the fall and winter.

b. The Sycamore-Canyon Community

Draws usually lead into canyons (V-shaped valleys). Here the vegetation is dominated by Bray oak (*Quercus brayi*), sycamore, Spanish oak, and Texas ash (*Fraxinus texensis*). Associated trees include hackberry (*Celtis reticulata*), *Juglans major*, escarpment cherry (*Prunus eximia*), Lacey oak, American elm (*Ulmus americana*), and cedar elm (*Ulmus crassifolia*). Ground vegetation is nearly absent, *Cyperus* sp., *Panicum* sp., Lindheimer muhlenbergia, green brier, and *Aristida wrightii* occurring in small quantities.

c. The Cypress-Stream Community

This community, though comparatively small in acreage, is extremely complex and highly variable. Cypress, river walnut (*Juglans rupestris*), Bray oak, and sycamore dominate the stream vegetation. A wealth of species, mostly forbs, is associated with these dominants, the composition and structure of the vegetation varying greatly with the size and topographic relationships of the streams. In Table 11 are listed some of the plants found along Kerr County streams.

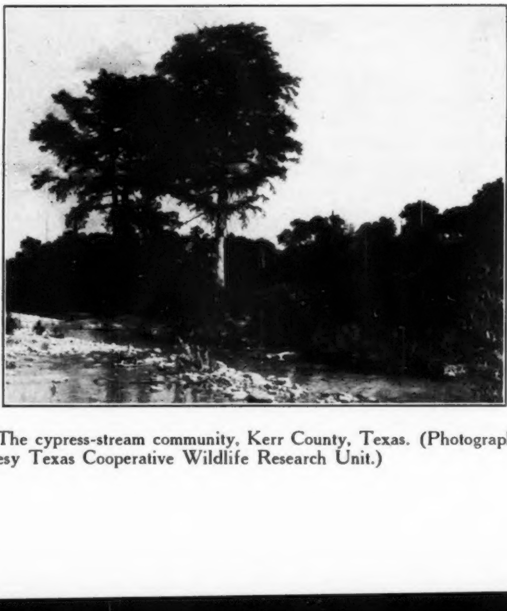

Fig. 8. The cypress-stream community, Kerr County, Texas. (Photograph by D. W. Lay. Courtesy Texas Cooperative Wildlife Research Unit.)

TABLE 11.—List of plants found in the Cypress-Stream Community.

Adiantum capillus-veneris	*Mentha spicata*
Aesculus discolor var. *flavescens*	*Mentzelia oligosperma*
Boehmeria cylindrica var. *drummondiana*	*Morus rubra*
Carya pecan	*Populus palmeri*
Celtis reticulata	*Prosopis juliflora* var. *glandulosa*
Cephalanthus occidentalis	*Prunus rivularis*
Cornus asperifolia	*Ptelea trifoliata* var. *mollis*
Diospyros texana	*Rhamnus caroliniana*
Dryopteris normalis	*Salix niger* var. *lindheimeri*
Eupatorium urticaefolium	*Salvia farinacea*
Fraxinus texensis	*Sophora affinis*
Garrya lindheimeri	*Tilia texana*
Hamamelis macrophylla	*Ulmus americana*
Ibervillea lindheimeri	*Ulmus crassifolia*
Ipomea trifida	*Ulmus flava*
Juglans major	*Verbesina lindheimeri*
Juglans rupestris	*Vitis rupestris*
Lonicera albiflora	

Interrelationships of Vegetation, Livestock and Deer

The present discussion deals with some of the effects of livestock and deer on the range vegetation of Kerr County; and conversely, some of the effects of the vegetation on livestock and deer. The interrelationships between livestock, deer, and vegetation are closely correlated with vegetative succession; some of them have been tabulated by Taylor and Buechner (1942).

EFFECTS OF LIVESTOCK AND DEER ON VEGETATION

GROUND VEGETATION

The most conspicuous effect of increased numbers of livestock and deer on range vegetation is to cause successive changes from communities higher in the scale of succession to communities lower in the scale. Most of Kerr County is at the present time in stages three and four. Alterations from stage one through stage six are caused primarily by livestock, though deer are in some cases a serious factor in addition to livestock. On the basis of the vegetative data presented above, and records of stocking employed in past and present livestock management, it was found that stocking rates near 100 animal units per section produced retrogressive succession. Furthermore, assuming a constant stocking pressure of such proportions, the rate of vegetative change increases as stage six is approached, the rate being least between stages one and two and greatest between stages five and six. That is, 100 animal units per section in stage one have less effect on the vegetation than the same number of units in stage three. In accord with this principle, as each stage is approached, from one through six, the number of animal units that may be supported in a particular stage decreases. Whereas 50 animal units may be maintained on some ranges in the first stage without changing the vegetation, only 20 or less may be maintained on ranges in the fifth stage. Moreover, as stage five is approached it becomes increasingly difficult to improve vegetative conditions while the range is stocked. On the average range in stage two, for example, about 50 animal units per section would allow the

vegetation to remain in that stage or advance toward stage one, the progress in this direction being most rapid in years of favorable weather conditions; while in stage five practically no stock can be placed on the range even in good seasons, if definite improvement is to be provided for. This concept is seldom recognized in Kerr County, and pastures usually remain in the same stage or deteriorate, improving only when exceptionally good years follow unfavorable years with poor vegetative conditions and comparatively low stocking.

Unless deferred rotation (not at present a common practice in Kerr County) is employed, stocking should be, as Talbot (1937) points out, for a slightly below average year to prevent overstocking during droughty years. When exceptional years follow, attempts should not be made to increase the stock to the carrying capacity of the range in those years. Though ranchmen claim the range cannot be stocked to capacity when the vegetation is rank during wet years, the loss from overstocking in the less favorable period following such years may far exceed the loss sustained in not using all of the forage in good years. In other words, understocking during the most favorable years may yield more profit on a long term basis than heavy increases in stocking during the best years.

ARBORESCENT VEGETATION

Shrubs

According to ranchmen, conspicuous changes have taken place in the shrubs that once formed a definite understory beneath the tree canopy. Some species have probably been eliminated entirely, others have been reduced to such an extent that they no longer provide a significant amount of forage. Most important of the species that have decreased in abundance are: ill-scented sumac, evergreen sumac (*Rhus virens*), *Rhus lanceolata, Forestiera neomexicana,* ribbon grass, wild plum, colima (*Xanthoxylum fagara*), round flowered catsclaw (*Acacia roemeriana*), dewberry, black haw (*Viburnum rufidulum*), *Bumelia texana,* and various species of grape. Both ill-scented sumac and *F. neomexicana* were the most abundant and important shrub species. These and the other species mentioned above are found at the present time only where browsing is light or moderate, or where protective shinoak, prickly pear, and other vegetation prevents browsing by deer and livestock. When browsing pressure is relieved, these species tend to return, though extremely slowly.

Blackjack and Spanish Oak

Grazing pressure affects tree species in several ways, the most serious being elimination of reproduction. This condition is most conspicuous in the blackjack and Spanish oak communities, although it is equally important in overbrowsed liveoak and shinoak communities. When not heavily overbrowsed, liveoak and shinoak reproduce by root suckers; but blackjack and Spanish oak sucker to a lesser extent, and usually grow into trees 10 to 20 feet tall. At this height the lower leaves are completely browsed, leaving a conspicuous browse line and giving the pastures a park-like appearance. Not only are reproduction

and shrubs eliminated in blackjack and Spanish oak communities; but as the trees continue to mature, the canopy closes, shading out and eliminating the valuable grasses also. This greatly reduces the carrying capacity for deer and livestock. Usually the tree reproduction and shrubs are eliminated before the grasses and forbs, leaving the range of value only for sheep and cattle.

Both the blackjack and Spanish oak areas cannot support the large populations of deer found on the liveoak-shinoak divide, less browse being available. Furthermore, since less browse is available from associated species, the Spanish oak communities can support only about half the number of deer that can be maintained in blackjack communities.

Liveoak and Shinoak

In the liveoak and shinoak communities elimination of seedling reproduction is less serious than in blackjack and Spanish oak communities, because root suckers are strong enough to perpetuate the tree species. In fact, reproduction by suckers under moderate grazing may cause liveoak and shinoak to spread over such a large extent of land that the desired proportions of grasses and forbs are materially reduced. It then becomes necessary to employ management practices that will reduce the amount of brush-like reproduction. Rapid spread of liveoak and shinoak is caused by browsing when the browsing pressure is not great enough to kill part of the suckers produced. Root suckers are produced when browsing eliminates foliage that would otherwise develop a normal tree crown. The food material manufactured by the tree is then utilized in reproduction by suckers at the roots. Long time records of ranchmen indicate that the desired balance between shinoak and liveoak browse and herbaceous vegetation is obtained when stocking in this type is at approximately 40 animal units per section, providing not more than 16 percent of this total is allotted to goats.

A serious loss is encountered when liveoak and shinoak mature and grow large enough to escape browsing. When this occurs normal tree growth is resumed, the remaining root suckers are killed by overbrowsing, and an increasing amount of leafage becomes unavailable to livestock and deer. The trees usually form small clumps set in the open grassland; crown canopies of these clumps are dense enough to shade out grasses and forbs, resulting in more or less sterile patches of land throughout the pasture. Though the mast crop continues to be of value to animal life, the ranges in this condition may be improved by appropriate management methods.

Cedar

One of the most significant effects of livestock on the range vegetation is in the spread of cedar. Although cedar is only slightly palatable to livestock, the fruit and a small amount of the foliage are eaten by goats and deer. Sheep and cattle also eat some of the fruit, while wild birds and mammals utilize the berries to a considerable extent. Since the seeds pass unharmed through the digestive tract, livestock and wild animals generally disseminate cedar widely over the range. Young cedar seedlings grow up almost unbrowsed.

Only under severe conditions of overgrazing is the foliage of cedar utilized by livestock or deer. Moreover, livestock reduce competition of grasses and forbs with the seedlings of cedar to such a degree that cedar invades grasslands easily where formerly held in check. Both dissemination of seeds and reduction in competition from other species are equally important in the spread of cedar over vast areas that might otherwise be occupied by the more valuable oaks and grasses. Most ranchmen in Kerr County today have observed the great spread of cedar that has taken place in the past 50 years or more. To many it has meant a serious struggle in economical management, and in recent years the federal government, through the Agricultural Adjustment Administration, has contributed considerable money for the eradication of cedar.

Usually cedar is correlated with heavy grazing and the three-awn stage of succession. It seems logical that maintaining the ground vegetation in the curly mesquite stage or better would help prevent the spread of cedar.

MULTIPLE USE

All classes of livestock, and deer too, feed on certain identical range forage plants. Multiple use of the range may result in the prompt extirpation of these plants, if stocking is too heavy. Stocking should be adjusted so that plants which are favored by one or more classes of livestock, such as little bluestem, sideoats grama, or ill-scented sumac, will not be eliminated.

According to Cory (1927), feeding studies carried out over a three-year period indicate that cattle are grazing animals, grazing over 75 percent of the time, but they eat a few weeds that sheep do not utilize. They also graze on cured grasses, while sheep seldom use dried forage. Sheep, likewise, are grazing animals, grazing nearly 80 percent of their time. They show a strong preference for weeds, but utilize grasses when weeds are not available. Goats are browsing animals, browsing approximately 53 percent of the year. When grazing conditions are good, goats prefer grazing, and may graze more than twice as much as they browse. Like sheep, they prefer succulent grasses and forbs; in the absence of such, goats do little grazing. Goats browse on over 25 species on the Edwards plateau; cattle browse on half that number, and sheep less than half as many as cattle. Whereas cattle and sheep seldom utilize mast, goats eat much fallen mast.

The present investigation has shown that in Kerr County deer are usually abundant enough to warrant considerations in livestock management programs. To what extent deer graze and browse has not been adequately determined; but indications are that deer are similar to goats in their choice of food, utilizing a considerable amount of browse and preferring to graze when grasses and forbs are in a succulent condition.

If ranges are to be properly utilized, it is extremely important that the differences in food requirements recognized above be carefully considered in stocking programs. Proper proportions of each class of livestock, together with deer, are just as important as the maximum number of animal units permitted

in each pasture. In the liveoak and shinoak savannas on the divide, for example, too many sheep in proportion to the number of goats will result in overuse of curly mesquite and underuse of shinoak or liveoak. The curly mesquite will be replaced by less valuable grasses and forbs of a lower stage in succession, while the shinoak or liveoak will spread rapidly by root suckers to cover a greater proportion of the pasture than is economically desirable.

In Table 12, taken from Taylor and Buechner (1942), are presented what are believed to be the proper proportions of livestock and deer for the average ranch in Kerr County. The allotments of each type of stock are based on observations of stocking in use and their effect on the vegetation.

TABLE 12.—Recommended head of livestock and white-tailed deer per section.

Class of Animal	Individuals	Animal Units
Cattle, breeding cows or their equivalent	18	18 or 36%
Sheep, ewes or their equivalent	140	20 or 40%
Goats, nannies or their equivalent	64	8 or 16%
Deer, does or their equivalent	24	4 or 8%
Totals	254	50 or 100%

EFFECTS OF VEGETATION ON LIVESTOCK AND DEER

Livestock

Cattle find vegetative conditions best in stage one, since they prefer grasses to forbs and utilize cured grasses. The proportion of cattle in stocking programs on ranges in stages one and two should be higher than in stage three. Pastures in stage three should carry more sheep than stage two to utilize the greater abundance of forbs. Goats require considerable amounts of browse, and should be eliminated from pastures where browse is scarce. Some ranchmen in Kerr County with land in blackjack and Spanish oak types have already greatly reduced or eliminated their goats, thus leaving the small amount of available browse for deer and making possible a desirable increase in browse through management practices.

White-tailed Deer

Numbers of deer are affected more by the amount of available browse than by the type of grasses and forbs. Both deer and livestock are responsible for browse conditions; but livestock, because of their greater numbers, are more responsible than deer. Of the three principal kinds of livestock in the region, goats have the greatest influence on availability of browse. Goats and deer are highly competitive; too many goats will force a reduction in the deer herd, the degree of reduction depending on how much browse remains available for the deer. Of course, too many deer produce the same effect as overstocking with goats.

In Table 13 are shown the population densities of white-tailed deer in various vegetative communities under various intensities of livestock stocking. The number of acres per deer is based on the census method previously

TABLE 13.—Results of White-tailed Deer Censuses under Various Vegetative Conditions and Grazing Pressures.

Area	Community	Length of cruise line (chains)	Estimated coverage of browse (percent)	Average number deer seen	Census results (acres per deer) 1st.	2nd.	3rd.	Average animal units of deer per section	Animal units of livestock per section Cattle	Sheep	Goats	Total animal units of livestock & deer per section
Liveoak-Shinoak Divide	Liveoak-curly mesquite	325		18								
	Shinoak-curly mesquite	161		11								
	Shinoak—three-awn	84		8								
	Spanish oak—draw	50		1								
	Liveoak—three-awn	10		4								
	Cedar—three-awn	10		7								
	Total	640	30–40	48	8.3	7.4	8.9	13.0	11.6	24.4	16.0	65.0
Blackjack Divide	Blackjack-little bluestem	351		5								
	Liveoak—Three-awn	109		13								
	Cedar—three-awn	80		7								
	Spanish oak—draw	75		2								
	Sycamore—canyon	25		0								
	Total	640	5–20	27	13.5	13.6	13.3	7.9	18.6	28.1	none	54.6
Liveoak-Spanish Oak Erosion Area	Spanish oak—three-awn	224		2								
	Cedar—three-awn	92		2								
	Liveoak—three-awn	88		1								
	Liveoak-muhlenbergia	76		2								
	Liveoak-buffalo grass	58		0								
	Cedar-grama	47		1								
	Liveoak-grama	32		0								
	Blackjack-grama	12		0								
	Shinoak-curly mesquite	11		3								
	Total	640	1–10	11	38.8	34.6	36.7	2.9	29.7	30.0	5.0	67.6

described. Deer were counted on the full eight miles of cruise line during each census; jumping distances were paced. Applying King's formula for grouse censusing, the number of deer seen was divided by the percentage of the area cruised to determine the total population on the area. This formula may be conveniently written:

$$\frac{\text{Total area (square yards)} \times \text{Number of deer}}{\text{Length of cruise line (yards)} \times \text{Twice jumping distance (yards)}} = \text{Total population}$$

In the present censuses the total area was two sections (6,195,200 square yards); the length of cruise line eight miles (14,080 yards). Calculations were converted to number of acres per deer by dividing the acreage (1280 acres) by the total population.

This census method is believed to be quite accurate in Kerr County where deer can be seen as far as 100 to 500 yards, or more. In the censuses made, no individuals jumped at distances greater than 150 yards were included, since such occurrences were rare and their inclusion would have resulted in misleading calculations. The method is perhaps less accurate in heavy brush and on areas where populations are low, and more accurate where many individuals are seen in areas of high populations, but this variation does not influence the validity of the results and conclusions presented here.

Hunting pressure on the first area, where deer are most abundant, is much less than on the remaining two areas; but since only about 29 percent of the bucks are taken annually on each of these areas, hunting has no effect on the populations. Leopold (1933) has shown that the population increase is scarcely affected even when 50 percent of the bucks are removed annually. Of course, does are protected by hunting regulations. If does were to be taken along with the bucks, the hunting would have a decided influence on the number of deer in a given area.

The data presented in Table 13 indicate that deer populations vary directly with the amount of available browse, which varies in turn with the type of vegetation and the livestock browsing pressure. More deer were observed in liveoak and shinoak communities than in any other vegetative community, and in the blackjack communities deer concentrated in the small, scattered areas of liveoak. Because of their more arborescent growth form, blackjack, post oak, Spanish oak, and other hardwood trees provide much less browse than liveoak and shinoak. Cedar provides little browse because of its relatively low palatability. Shrubs, such as agrito, ill-scented sumac, *Rhus lanceolata,* wild plum, *Forestiera neomexicana,* and green brier, provided considerable browse in blackjack and Spanish oak communities prior to their reduction or elimination by livestock (particularly goats) and deer. Liveoak and shinoak form brush-like growths which, together with their high palatability and abundance, make them the most valuable browse species. Wherever these species are available, deer occur in greatest numbers.

Availability of liveoak and shinoak depends to a large extent on the amount of competition offered by goats. Where goats over a long period of

years have eliminated much of the browse, deer populations are reduced. As goats and deer reduce the amount of browse, they turn more toward grazing. When deer are forced to graze heavily, they not only suffer from lack of proper nutrients, but also become infected with stomach worms that are prevalent on nearly all ranches in Kerr County. Dr. H. L. Van Volkenburg, of the Department of Veterinary Parasitology at the Agricultural and Mechanical College of Texas, has found stomach worms, *Haemonchus contortus* (Rudolph), abudant in several emaciated deer taken in Kerr County. Through malnutrition and related diseases, especially the disease caused by stomach worms, deer populations decrease until the proper balance between available browse and utilization requirements is met. Such decreases in browse and deer numbers have been observed on many ranches in Kerr County.

The deer censuses representing the Liveoak-Shinoak Divide in Table 13 were made on a 55,000-acre ranch, where grazing and browsing conditions were exceptionally good. Deer populations are higher here than on any other ranch in Kerr County. On this ranch the foreman has observed a gradual decrease in the amount of liveoak and shinoak browse, as well as curly mesquite grass, during the past 20 years. It seems logical that a slight reduction in the total number of animal units and the proportions of goats and deer is necessary, if the valuable browse species and grasses are to be sustained.

The populations of deer on the Blackjack Divide and the Liveoak-Spanish Oak Erosion Area are small as compared with the population on the Liveoak-Shinoak Divide. The limitation in the amount of available browse due to the growth form of blackjack and Spanish oak, together with the great reductions in all browse species caused by goats and deer, are responsible for the much lower populations of deer on these areas. While no goats occur at the present time on the ranch here representing the Blackjack Divide, they had existed previously in large numbers. When browse became scarce, goats were eliminated completely to provide the deer with the comparatively small amount of browse remaining. If the goats had been maintained, continued reductions in the browse would have caused large decreases in the deer herd.

On the ranch representing the Liveoak-Spanish Oak Erosion Area, the ranchman has observed a decrease of about 50 percent in the deer herd during the past 15 years. This reduction is correlated with corresponding decreases in the amount of available browse. The number of goats on this ranch was reduced to only six percent of the total number of livestock units to assure a continued, healthy deer population.

Since about 24 percent of Kerr County is in cedar, it is unfortunate that more information of relationships between livestock, deer, and cedar was not secured. Indications are that cedar communities are used considerably by deer for protection. Some grasses, forbs, and browse, especially shinoak, are available in this type of vegetation; but its greatest value to livestock and deer is for protection during the heat of the day in summer and during the periodically severe weather conditions (northers) in winter. Where cedar occurs, it seems economically desirable to maintain at least limited areas, especially if

such areas can be coincident with watersheds, rather than to eradicate all of the cedar as has been the usual practice in the management of cedar.

Summary

The investigation reported on here deals with the range vegetation of Kerr County, Texas, and some of its associated livestock and deer relationships. The natural vegetation of the county is a more or less open oak grassland, with some cedar occurring in small areas, probably under natural conditions, on steep, rocky slopes unsuitable for the establishment of the oaks. In accordance with physiographic and edaphic factors, the various oaks segregate into well-defined communities. Shinoak is found correlated with thin, rocky soils at the highest elevations; liveoak with the deeper soils on gentle slopes and bottomlands; Spanish oak with the caliche soils of steeper slopes and in headwater draws; and blackjack oak with siliceous soils. Stream vegetation is usually dominated by sycamore, Bray oak, hackberry, river walnut, pecan, and cypress. The vegetation of Kerr County may be divided into five areas: (1), the Liveoak-Shinoak Divide; (2), the Blackjack Divide; (3), the Liveoak-Spanish Oak Erosion Area; (4) the Cedar Brakes; and (5), the Riparian. Each of these areas is composed of various communities that are determined in part by soils and physiography, and in part by livestock grazing pressures. Generally, the arborescent vegetation is determined by the former, and the ground vegetation by the latter. The various ground vegetation communities follow well-defined stages of secondary succession, and depend upon the degree of livestock grazing pressure. In retrogressive order these communities or seral stages are: (1), the climax, dominated by little bluestem grass and speargrass; (2), the grama stage, dominated by sideoats grama and hairy grama; (3), the buffalo grass or curly mesquite stage, dominated by neither one of these grasses, depending upon the amount of available soil moisture; (4), the three-awn grass stage, dominated by red three-awn, Reverchon three-awn, and *Aristida wrightii;* and (5), the forb stage, dominated by unpalatable forbs such as mealy sage, *Evax* spp., and hoarhound. The most economical of these stages to maintain on the average ranch in Kerr County are the grama stage and the curly mesquite stage.

Range lands in the county are mostly stocked at 70 to more than 100 animal units per section. These rates of stocking cause the elimination of the valuable, more palatable grasses and produce the three-awn grass or forb stage of succession. Much of the ground vegetation at the present time is in the three-awn seral stage; only on properly stocked ranges are curly mesquite or grama grasses dominant. Indications are that not more than 50 animal units (including deer) should be placed on one section of 640 acres.

Many of the ranches are leased for white-tailed deer hunting. Since deer provide a substantial portion of the ranch income, it is desirable that they be maintained in shootable numbers on a sustained yield basis. A critical problem in the maintenance of shootable white-tailed deer populations, though not yet manifest on all of the range lands of the county, is the control of available browse. Overstocking with goats has been responsible for great reductions in

available browse; and if the practice is continued, declines in the deer population are inevitable. The range lands of Kerr County are particularly well-adapted for the production of deer; effort should be directed more completely toward the inclusion of these animals in the range management programs. Maintenance of more favorable vegetative conditions, through lighter grazing and direction of management practices to include deer as well as livestock, should insure the continuance of deer in shootable numbers.

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The Biology of the American Lotus, Nelumbo lutea (Willd.) Pers.

Thomas F. Hall* and William T. Penfound*

Nomenclature

Small (1933) in his "Manual of the Southeastern Flora" designated the American or yellow lotus as *Nelumbo lutea* (Willd.) Pers. Synonyms include *Nelumbium luteum* Willd., *Nelumbo lutea* Pers., *Nelumbium pentapetalum* Walt., *Nelumbo pentapetala,* and *Nelumbium codophyllum* Raf. The latter name was given by Robin (1817) to the lotus plants in Louisiana which were said to be much larger than those of *Nelumbium luteum*. Examination of lotus colonies in Louisiana suggests that the larger size is to be attributed to the richer soils and longer growing season. The concensus among botanists seems to be that there is only one species of native lotus in America.

Some of the unusual characteristics and uses of the plant are reflected in the thirty-seven common names which have been compiled from various sources. Among the more revealing are great yellow lily, duck acorns, yocker-nut, monocanut, water nut, rattle nut, rattle box, yonkapin, water chinkapin, watering can, can dock, and alligator buttons.

Distribution

The American lotus is an emergent aquatic herb of wide distribution in North America. Tricker (Bailey, 1933) indicated that the yellow lotus was not known to the white man prior to its discovery in America. It was well known, however, by the American Indians who conducted extensive aqui-cultural practices with the species. Tricker referred to it as being abundant in the central states but as being scarce in the Middle Atlantic and eastern states.

Small (1933) lists the species as being found in "ponds, lakes, and slow streams, coastal plain and isolated localities in other provinces, Fla. to Tex., Neb., Minn., Ont., and Mass."

Tricker (Bailey, 1933) pointed out that the American lotus was cultivated in the waters of the Tennessee and Cumberland Rivers by the aborigines and that the species was carried northward and eastward by them. At present in the Tennessee Valley, the species occurs in cool spring-fed pools, limesinks, and in the "river-lakes" of the Tennessee Valley Authority. It is well established on Lake Wheeler which was impounded in 1936. Additional colonies have been recorded from the Kentucky, Wilson, Guntersville, and Chicamauga Reservoirs, but it is not known to occur in any of the other impoundments of the Authority (Fig. 1).

* Laboratory Services, Health and Safety Department, Tennessee Valley Authority, Wilson Dam, Alabama. Submitted September 1, 1942.

Ideal sites for the lotus in recent impoundments are cut-over tupelo gum swamps where the water ranges from one to six feet in depth. Well-established colonies have been observed in many other sites, however. One excellent colony has been inspected on the inundated natural levee of the Tennessee River at Decatur, Alabama, where the plants were thriving in water as much as eight feet in depth and where they were subjected occasionally to severe wave action. In general, however, the yellow lotus does best in water about two to six feet deep in the reservoirs of the Tennessee Valley Authority.

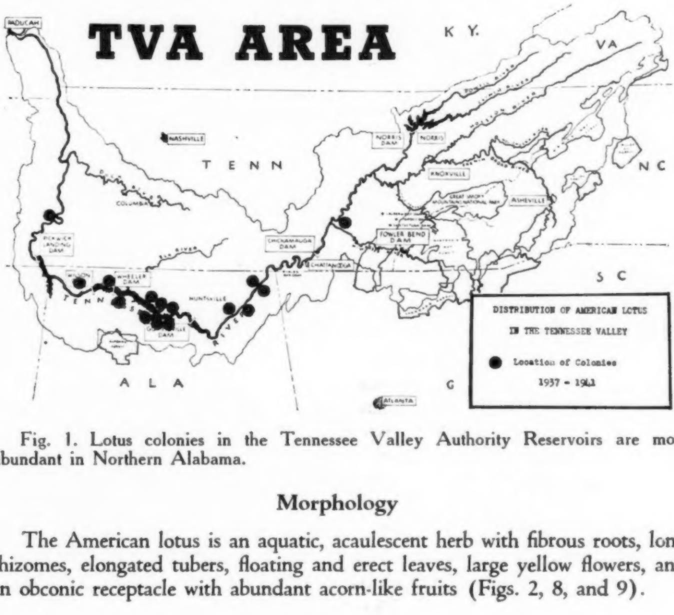


Fig. 1. Lotus colonies in the Tennessee Valley Authority Reservoirs are most abundant in Northern Alabama.

Morphology

The American lotus is an aquatic, acaulescent herb with fibrous roots, long rhizomes, elongated tubers, floating and erect leaves, large yellow flowers, and an obconic receptacle with abundant acorn-like fruits (Figs. 2, 8, and 9).

Roots

The roots of the American lotus are fibrous and are produced in abundance at the nodes of the rhizome. It is of interest to note that the root system of lotus is entirely adventitious since a functional primary root does not develop from the seed. Roots three millimeters in diameter and fifty millimeters in length were encountered frequently. A major portion of the root consists of aerenchyma which constitutes most of the cortex (Fig. 3). The root of lotus does not function as a vegetative reproductive structure, as is true with certain other aquatics, such as alligator weed (*Achyranthes philoxeroides*).

Rhizomes

The rhizomes are of two types: slender (6 mm. to 8 mm.) and large (8 mm. to 20 mm.). The slender (white) ones usually were found within the

top four inches of the soil, whereas the larger rhizomes (white or pink) were established to depths of 18 inches. Where the species occurs in pure stand the rhizomes form a complex underground network which total a length of 45 miles per acre. The rate of colonization is phenomenal since a small patch was observed to extend itself radially an average of 45 feet in one growing season. This represents a growth rate of 0.23 feet per day for the entire summer. On this basis six properly spaced patches of lotus (10 feet across) would produce an acre of lotus during one growing period.

Features of interest in the structure of the rhizome include the closed vascular bundles scattered throughout the parenchyma, six (usually) large air tubes and a number of smaller ones which in aggregate occupy approximately forty per cent of the rhizome, an epidermis composed of thick-walled cells, and a very narrow band of poorly developed collenchyma just below the epidermis. With the exception of a reduction in the peripheral band of supporting tissue and a greater volume of air channels (40% vs. 15%), the general internal features of the rhizomes are similar to the peduncle (Fig. 4).

LEAVES

The leaves of lotus are alternate, dimorphic, orbicular, centrally peltate, blue-green on their upper surfaces, and pale gray-beneath. The leaf arises from the upturned rhizome tip and is included in a large stipular sheath. The terminal bud of the "runner" continues to push its way through the compact soil and gives rise to an internode and leaf. The internodes varied from four to sixty inches, their length usually varying in the same direction as the water depth. The young leaf blade is laterally inrolled and stands oblique to the petiole. The expanded leaves are as much as three feet in diameter and usually exhibit 25 prominent radially disposed veins (Fig. 2). Of these, 24 branch dichotomously near the periphery of the leaf but the remaining vein does not produce a bifurcation.

The mature leaves are either erect or floating with the leaf blade perpendicular to the petiole. The strongly concave erect leaves usually stand four feet (1 to 6 ft.) above the existing water level, the length of the petiole being conditioned by the water depth. The flat floating leaves generally are attached to looping petioles. Water does not wet either the erect or floating leaves but forms drops which look like quicksilver (Fig. 2). It was found that an aggregate of more than 75,000 leaves (55,000 erect) prevailed on each acre in well-developed colonies. Concerning the leaf types, it has been demonstrated that floating and erect leaves are common on both small and large rhizomes. Floating leaves are usually the first to appear in colonies originating from seed, at the margins of old colonies, and after cutting or mechanical injury to the plant. The presence of floating leaves only in a colony is interpreted as an indication of its youth or the survival of a stand in water deeper than the optimum for the species.

The structure of the leaf as revealed by a vertical section through one of the large veins is interesting. The upper surface of the leaf is covered by numerous papillae which apparently prevent water from wetting the lamina.

Stomata are present only on the upper surfaces of both floating and erect leaves. Other features of interest include the upper and lower bands of collenchyma, the relatively large air tubes, and sheathed bundles embedded in a groundwork of parenchyma (Fig. 6). The petioles contained numerous scattered bundles and were quite similar in structure to the normal peduncle (Fig. 4). It was noted that a smaller number of large air tubes usually obtained in the petioles as contrasted to the peduncles (4 vs. 6). Measurements of air tubes indicated that they occupied approximately twenty-five per cent of the cross-sectional areas in the petioles of erect and floating leaves.

FLOWERS

In the Tennessee Valley, flowering is usually initiated by June 1, but often it is deferred as late as July 1 especially after severe winters. Lotus colonies do not "flower all at once" but continue to produce blossoms freely until one month before the growing season is terminated.

The erect, showy, cream-colored, fragrant flowers attain a diameter as much as nine inches when fully expanded (Fig. 9). They occur singly on

Fig. 2. Water does not wet either the erect or floating leaves but forms drops which look like quicksilver.

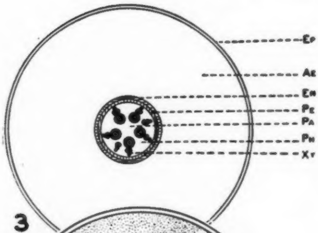
long, erect peduncles from two to six feet above the water surface and from one to two feet above the leafy horizon (Fig. 2). Flowers produced early in the season have relatively short peduncles, but, as flowering proceeds, the peduncles become progressively longer. Each flower is actinomorphic, perfect, hypogynous, and consists of an indefinite number of floral elements arranged spirally about the central axis (Fig. 9). The components of the perianth present a graded sequence from the lowermost sepal to the uppermost petal which makes it difficult to delineate the calyx from the corolla.

The calyx usually consists of two to five persistent petaloid sepals which contain very little chlorophyll. Each sepal is boat-shaped, slightly keeled, and terminates in a mucronated tip. The sepals are usually twice as long as their maximum width near the base (1.5 x 0.75 in.). They exhibit parallel venation with one prominent midvein and fifteen smaller parallel veins on either side.

Two series of petals are present in the corolla, transitional petals and true petals. The transitional series is composed of five to eight floral elements which are cream-colored at the base and faint green distally. These petals are boat-shaped, elliptical in outline, widest near the middle, and possess a slightly emarginate apex subtended by a dark mucro on the lower surface. Thirty to forty prominent parallel veins are usually evident with an obscure vein between the main veins. The true petals range in number from seven to thirteen and are distinguished by the deep cream-colored base and the light cream-colored distal portion. They are boat-shaped, elliptical to spatulate in outline, widest above the middle, and exhibit an emarginate apex subtended by a cream-colored mucro. The midrib is inconspicuous and the prominent parallel veins progressively decrease in number (35 to 20) from the outer to inner true petals.

The androecium is composed of approximately 200, often tardily deciduous, stamens (Fig. 9). Evidence of petalody was often present. Each stamen resembles a miniature "walking stick" and is composed of three parts. At the top is a cream-colored appendage which corresponds to the curved handle of the "walking stick." Below the handle is the elongate orange anther which is borne on a slender, yellow filament. The appendages are curved, point centripetally, and often rest on the upper surface of the receptacle. The appendages on the stamens adjacent to the ovary are bent near their junctions with the anthers, whereas the peripheral ones are curved inwards at higher levels. The anthers are narrow elongated structures composed of two "cells" separated by a connective on the inner surface. At maturation, the cells split lengthwise along their outward faces and expose the large smooth, yellow, spheroidal, sticky pollen grains.

The spheroidal pollen grains in a newly opened anther average 67 microns in diameter and exhibit three large meridional furrows, equidistantly disposed about the equator. Several hours after the anther dehisces, the lateral walls of the pollen grain's furrow are drawn close together, presumably due to drying. As a result, the pollen grains become ellipsoidal with three narrow longitudinal furrows. The change in shape is accompanied by a slight increase in length of the polar axis and a marked decrease in the equatorial diameter. Pollen



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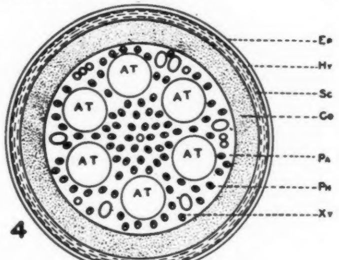

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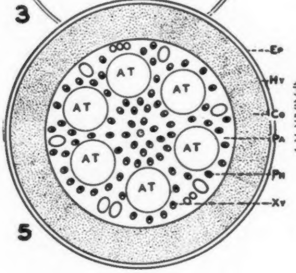

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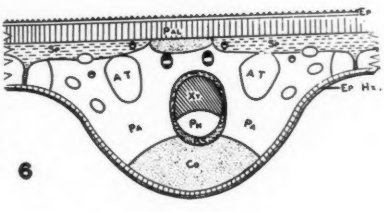

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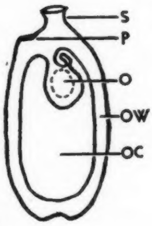

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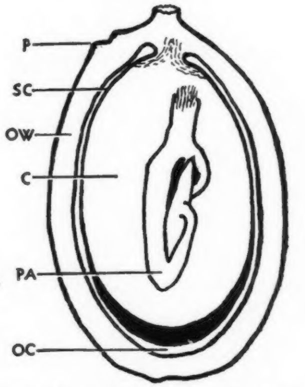
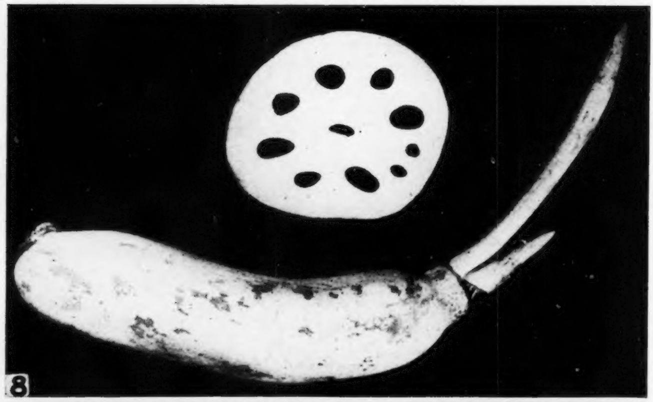


7b

Fig. 3. The root is well supplied with aerenchyma, root ×16. Ep—Epidermis. Ae—Aerenchyma. En—Endodermis. Pe—Pericycle. Ph—Phloem. Xy—Xylem. Pa—Parenchyma. Fig. 4. The normal peduncle possesses continuous bands of collenchyma and sclerenchyma. Normal peduncle, ×3.3. See legend of Fig. 5.

Fig. 5. The peduncle in the region of response just below the torus differs from the normal peduncle in that it lacks sclerenchyma, ×3.3. Ep—Epidermis. Hy—Hypodermis. Sc—Sclerenchyma. Co—Collenchyma. Pa—Parenchyma. Ph—Phloem. Xy—Xylem. AT—Air Tube. Fig. 6. A vertical section of the leaf through a vein reveals a papillose upper surface, sheathed bundles, air tubes in a ground work of parenchyma, and upper and lower bands of collenchyma. Vein of erect leaf, ×16. Ep—Epidermis. Hy—Hypodermis. Pal—Palisade Layer. Sp—Spongy Parenchyma. Co—Collenchyma. Pa—Parenchyma. Bs—Bundle Sheath. Xy—Xylem. Ph—Phloem. AT—Air Tube.

Fig. 7a. Median section of young ovary, ×2.7. Fig. 7b. Median section of green (viable) fruit, ×2.7. C—Cotyledon. O—Ovule. OC—Cavity of Ovary. OW—Ovary Wall. P—Protuberance.—PA—Plant Axis. S—Stigma. SC—Seed Coat.



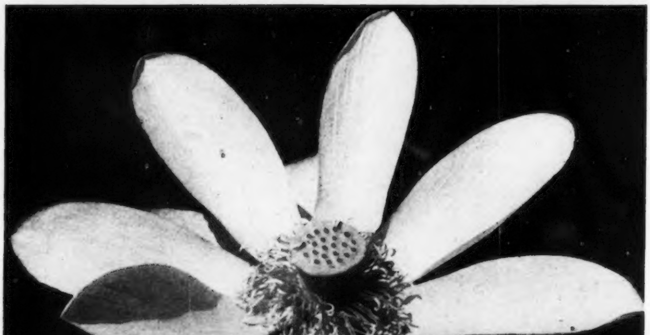


Fig. 8. The tubers are banana-like in appearance, and well supplied with air tubes, ×1.

Fig. 9. The large, exquisite flowers open in the morning and close at night, ×1/2.

grains exposed to the atmosphere averaged 72 microns in length but only 46 microns in width.

The gynoecium normally consists of 12 to 25 pistils which are embedded in a large, spongy receptacle composed mostly of aerenchyma (Fig. 9). The receptacle is an inverted truncate cone from 1 to 1.5 inches across its face and about 1.5 inches high. The flat surface is a rich sulphur color, whereas the conical surface of the torus is cream-colored. At late maturity the entire torus becomes a rich chocolate brown. Each pistil consists of a large basal ovary shaped like a cylindrical flask, a very short style (often absent), and a golden saucer-shaped stigma with a depressed, flaring surface.

The ovary is attached basally to the receptacle. It is an erect cylinder ($1/4$ x $1/8$ in.) with a peculiar protuberance near its distal end, facing the periphery of the torus. The ovary is uni-carpellate, one-celled, and includes a single ovule. The small white almost spheroidal ovule hangs acentrally from the ceiling of the cell. It is opposite the unusual protuberance pointing with the free end centripetally (Figs. 7a, 7b). After fertilization is effected, the ovule grows towards the floor of the cell. Growth is more rapid at its distal end and the immature seed takes in the appearance of a miniature light bulb hanging from the ceiling of the cell. Before fertilization occurs, the ovule occupies but a small fraction of the cell, but, as the fruit matures, most of the cavity is filled. A small air space remaining at the base of the fruit plays an interesting role in dissemination and germination (Figs. 7a, 7b).

The fruits are nuts which are borne in cavities of the receptacle. The green fruits entirely fill the cavities of the torus. This condition continues until the fruits mature, at which time they are chocolate in color. Later these fruits shrink to one-third their original volume and change to a deep grape-purple color. These changes are associated with a loss in water from the ripening fruits, the water content being reduced from 59% to 7% (Table 1). The pericarp is composed of a wavy outer covering, a thick middle layer, and a reticulate inner layer. The seed is composed of two thin seed coats, presumably two fleshy cotyledons, and a *green* embryo. Each embryo is upside down in the fruit and consists of two prominent inrolled, orbicular, peltate leaves and two concealed embryonic leaves (Figs. 7a, 7b).

The reproductive cycle in lotus includes several interesting physiological phenomena. The flower buds and flowers are always erect. The blossoms open in the morning and close at night and, usually fall two days after the initial opening of the buds. Within four days after the petals are shed, the receptacle bends downward about forty-five degrees and takes a position with the torus face toward the east (Fig. 10). The stimulus is not known, but the region of response is located in the peduncle about one inch below the torus. This portion of the peduncle differs in structure from the normal peduncle in that it lacks the peripheral band of sclerenchyma (Fig. 5). By the time early maturity of the fruits has been reached, the receptacle has become greatly expanded especially in the radial direction and has changed its position almost to a right angle to the main axis of the peduncle. As the fruit shrinks and

10

11

Fig. 10. The buds and flowers are erect, but the torus turns eastward and downward to the horizontal position by early maturity. The torus again becomes erect but later falls off.

Fig. 11. Flood waters destroyed the leaves and many of the rhizomes of the lotus, but the remaining rhizomes produced a few small leaves of the floating type.

hardens, the peduncles with the fruiting bodies again assume an erect position (Fig. 10). The fruiting heads then turn brown and move downward through an arc of 180 degrees, the peduncle finally breaking in the region of response. By this time the water content has decreased to an average of 8 per cent (Table 1). The detached fruiting receptacles now float on the surface of the water. Receptacles at least one year old, containing viable fruits, have been found floating in our reservoirs. This is probably due to shoreline stranding and refloating, both of which are probable factors of importance in the continuing colonization of the species.

Germination

Fruits are capable of germination while they are near their maximum size but retain their viability subsequent to shrinkage. Fifty fruits and fifty seeds (peeled fruits) of the chocolate-brown (near maximum size) and grape-purple (near minimum size) types were placed in water in the laboratory and kept under observation for four weeks.

The chocolate-brown fruits sank to the bottom at once due to their high specific gravity (1.14) (Table 1). Five hours later, ninety per cent were floating at the surface with the stigma down which resulted in the embryo being right side up. This inverted position is produced by an air space which is located near the base of the fruit (Figs. 7a, 7b). After twelve hours of floatation, the fruits returned to the bottom until germination occurred. The shells split longitudinally six days after the fruits were placed in water, but ten days usually elapsed before most of the seedlings emerged. At that time, the young plants with inrolled leaves again returned to the surface. Twenty-five days after the experiment was initiated, the plants were 45 centimeters long, the four young leaves were unrolled, and small roots were present at the base of each leaf. The average growth rate after the emergence of the embryo was found to be 2.5 cm. per day, but rates as high as 12 cm. per day have been recorded shortly after emergence of the embryo.

The peeled, chocolate-colored fruits all sank to the bottom when placed in water. All the seeds germinated in one or two days and after five days

TABLE 1.—Water Content, Volume, and Specific Gravity of Tori and Fruits of American Lotus.

Torus	After Anthesis	With Green Fruit	With Purple Fruit
Per Cent Water in Torus	*77	72	8
Fruits	**Green**	**Chocolate**	**Grape Purple**
Per Cent Water in Fruit	59	50	7
Volume of Fruit (cc.)	1.85	1.55	0.60
Vol. oven-dry Fruits (cc.)	0.85	0.90	0.55
Per Cent Decrease in Vol.	54	40	8
Sp. Gr. of Fruit	1.09	1.14	1.14
Sp. Gr. of Oven-dry Fruit	1.00	1.00	1.14

* All figures, one determination only.

most of the seedlings came to the surface and remained there throughout the experiment. The removal of the shell affected the germination process in three ways: (1) accelerated the emergence of the embryo by approximately seven days, (2) increased the percentage of embryos which successfully emerged, and (3) eliminated one cycle of vertical movements of the fruit in water.

Grape-purple fruits were tested during the growing season they were produced and one and two years later after storage at room temperature. Ninety per cent of all these fruits sank when placed in water, but none of these returned to the surface or germinated. Maintaining the fruits in ice for a two-week period failed to make them permeable to water. All other efforts to germinate mature fruits without treatment have yielded negative results to date. However, the seeds which they contained germinated readily when the impervious shells were removed, punctured, or treated with concentrated sulphuric acid.

Many research workers have investigated the germination pattern of lotus fruits. Ohga (1926) reported that all of the fruits of *Nelumbo nucifera* germinated after lying in moist peat beds of South Manchuria for at least two hundred years. Protracted dormancy in the American species is probable, but its proof remains to be demonstrated. Ogha (1926) also found that the fruits contained 0.2 cc. of gas, of which 18.33 per cent was oxygen. He showed that the fruits contained sufficient oxygen for initiating growth by successfully germinating them in oxygen-free media, whereas fruits with the air expelled failed to germinate in similar media. Jones (1928) found that fruits might be successfully prepared for germination by treating them with concentrated sulphuric acid for five hours. Shaw (1929) pointed out that treatment of fruits with some fat solvent, as ether, permitted the entrance of water with subsequent germination. Meyer (1930) also obtained normal embryos after the fruits were made permeable to water by treating them with Schweitzer's reagent for 75 to 200 hours.

Seedlings have been collected from sites at some distance from stands of lotus in Guntersville and Wheeler Reservoirs. It is probable that field germination occurs frequently, but it is apparent that only a very small percentage of the fruits germinate. It would be of interest to know what are the factors or agencies involved in nature whereby the impermeability of the fruit coat is overcome. The well-developed seedlings float on or near the water surface, are ultimately stranded by wave action, and strike root near the water's edge.

The young plant which develops from the seed exhibits four small peltate leaves, a rhizome, and rootlets at the nodes. The second internode of the rhizome increases in diameter and forms a tuber. Shortly thereafter, the young leaves succumb. Meyer (1930) observed this pattern of growth in many seedlings and followed in detail the further development of the plants. He states:

> If the underground parts were not examined, one would be apt to think the plants were dying. This striking behavior is a perfectly normal condition. Within three weeks after the temporary arrest in development new tissue develops from the tuber and its enlargement is very rapid, the rhizome extending through the soil, and leaves and roots appearing at the nodes which occur at quite regular intervals.

Other Features

Certain other features of the lotus merit consideration at this point. Starch grains were abundant in the tubers, rhizomes, and seeds. The grains were mostly oval to round in outline and exhibited well-defined concentric lamellae. Simple starch grains were encountered most frequently but doublets were also noted as being common. The smallest starch grains in the tubers and rhizomes were in the cells just beneath the epidermis but were progressively larger centripetally. The largest starch grains (71 microns long) were found in the deeper lying parenchyma cells.

Latex is present throughout the vegetative body and exudes readily from injured petioles, leaf blades, and peduncles. The spiral thickenings of the xylem form long silky strands which are most conspicuous in the petioles, peduncles, and rhizomes. Crystals were abundant along the walls of the air tubes which run throughout most of the vegetative body. Another interesting feature is the fact that gases frequently bubble from the injured lamina of leaves and severed petioles.

The water content of the various vegetative parts of the lotus is directly correlated with their functions. The highest per cent of water was found in the rhizomes and tubers (parts of rhizomes) where little mechanical tissue is present (Table 2). As might be expected the larger the rhizomes the lower was the water content. This is related directly to the greater quantity of starch found in the larger rhizomes. Of the leaves, both the petioles and blades of the erect leaves possessed less water than their counterparts in the floating leaves (Table 2). This is explained by the greater quantity of mechanical tissue in the erect leaves. As was to be anticipated the peduncles possessed a relatively low moisture content due to their function of support.

Effect of Fluctuation

Small colonies of lotus were known from Wheeler Reservoir in the fall of 1936 when closure of the dam was effected. The species did not spread rapidly

TABLE 2.—Water Content and Dry Weight of Vegetative Parts of the American Lotus.

Plant Part	Water Content (Per cent)	(Grams per foot) Dry Weight
Small, white rhizome	*94	0.3
Large, white rhizome	91	2.6
Large, pink rhizome	89	2.7
Tuber	88	9.4
Petiole, floating leaf	87	1.1
Petiole, erect leaf	79	1.5
Peduncle, after Anthesis	79	1.5
Floating leaf	81	....
Erect leaf	75	....

* All figures, one determination only.

during 1937, presumably due to low water levels during the latter half of the summer of 1937. During the 1938 growing season an increase in lotus colonies was observed. During 1939 normal water levels were approached closely and lotus colonies were produced in profusion, particularly in backwater areas.

Summer floods of 1940 had a deleterious effect on many colonies of lotus in Wheeler Reservoir where water levels in backwater areas were from five to seven feet above the anticipated pool level (Fig. 11). This meant that colonies of lotus were submerged under two to four feet of turbid water for several days. Low water during the early part of the summer of 1941 resulted in death to the leaves of dewatered colonies, and flood backwaters of July defoliated many of the colonies anchored at lower contours. It was observed that complete inundation for a single two-week period was sufficient to destroy the leaves of lotus, whereas at least one month of complete dewatering occurred before most of the leaves of stranded colonies succumbed. Colonies of lotus on Wilson, Guntersville, and Chickamauga Reservoirs did not exhibit any injury as a result of summer floods since the amplitude of water levels on these reservoirs was markedly less.

The destructive effect of submergence to lotus in the Wheeler Reservoir was somewhat unexpected. During certain floods the petioles were snapped off just below the leaf blades with the result that great windrows of "leaves" were piled along the shoreline. In at least one period of inundation the water submerged the entire leaves with subsquent destruction of the intact leaf (Fig. 11). After all floods of more than two weeks duration many of the rhizomes and all of the flower buds, flowers, and immature tori were destroyed. In most cases a few viable rhizomes remained which produced a few, small, floating leaves. From such weakened colonies small flowers appeared with tori which contained only a few (usually 2 to 10) fruits. In one flower only one pistil and one fruit developed. From the above facts it is readily evident that summer floods constitute an important factor in limiting the colonization of the American lotus in the reservoirs of the Tennessee Valley Authority.

Control

Since the lotus provides environmental conditons suitable for the development of malaria mosquitoes, methods of controlling the plant have been developed. Sodium arsenite was applied as an herbicide both by a hand duster and by airplane to plots of lotus. Data from field plots indicate that three treatments of 20 pounds per acre at approximately three-week intervals were more effective than a single treatment of 150 pounds per acre. This suggests that the herbicide did not penetrate through the water to the rhizomes to any extent and that the main value of the treatment was in the destruction of the leaves. This is supported by the fact that the poison was much more efficient in dewatered areas. It is probable that treatment of lotus with an herbicide has the same effect as cutting off the leaves and may be utilized in a similar manner as a control measure.

Recurrent cutting has proved effective in arresting the spread and in reduc-

ing the areas of stands of lotus. This method of control is practiced routinely on all reservoirs where the lotus has been encountered. It is desirable to initiate cutting operations previous to the opening of the first flower buds or about June 1. This is deemed advisable because: (1) the plants, apparently, are most vulnerable at this time since much of the reserve food has been expended in putting forth new growth; (2) the area requiring treatment is much less than if operations are deferred until later in the growing season; (3) the early cutting permits approximately three retreatments during the same growing season if resprouting occurs; and (4) the possibility of the dissemination of the species by means of fruits is avoided. The number of cuttings necessary to attain success is dependent upon water depth and turbidity, the greater the water depth and the poorer the light penetration, the smaller the number of cuttings necessitated. Colonies in deep, turbid water, with floating leaves only, were eliminated by a single cutting but stands in clear, spring-fed pools persisted after two seasons of mowing. The cutting of lotus plants near the termination of the growing season should be avoided since growth activities of the plants have decreased sharply.

A mechanized underwater weed-cutter was employed on Wheeler Reservoir during the 1940 and 1941 growing seasons. The unit mows from 2 to 9 acres of lotus per day, depending on the number of stumps. The acreage of lotus on Wheeler Reservoir has been greatly reduced since the 1939 growing season. Following mowing, disposal of the severed parts was not necessary since the leaves were either stranded or sank within seven days. The results obtained on Kentucky, Wilson, Guntersville, and Chickamauga Reservoirs by cutting lotus recurrently are very encouraging. Experience with the American lotus has demonstrated that the species can be controlled effectively on new impoundments by pursuing the four cardinal points of control: (1) early discovery; (2) proper treatment; (3) continuing vigilance for resprouting; and (4) retreatment.

Summary

1. The American lotus, *Nelumbo lutea* (Willd.) Pers. is a perennial, emergent, aquatic herb with fibrous, adventitious roots, slender rhizomes, elongated tubers, erect and floating leaves, large fragrant, yellow flowers, and an obconic torus containing acorn-like fruits.

2. The roots are characterized by a large, aerenchymous cortex; the rhizome, tubers, petioles, and peduncles are distinguished by a small cortex, scattered bundles, and four to eight large air tubes; the midveins of the leaf are characterized by upper and lower masses of collenchyma, closed bundles, and air tubes in a groundwork of parenchyma.

3. The rapid colonization of new areas by lotus is accomplished by the elongated rhizomes and to a less extent by tubers and fruits. Complete inundation of lotus colonies for a continuous period of two weeks or dewatering for one month destroyed all the leaves and flowers and many of the rhizomes and tubers.

4. The American lotus provides favorable environmental conditions for the development of malaria mosquitoes, but it can be controlled effectively by recurrent cutting of the leaves where the water is relatively turbid.

ACKNOWLEDGMENTS

This study was conducted under the supervision of Dr. E. Harold Hinman, Senior Biologist, to whom thanks and appreciation are hereby extended. We desire to express our thanks to Dr. A. D. Hess for the loan of his photographic equipment and for Figs. 2 and 9. We also desire to acknowledge the help of Mrs. Faith Mackaness, Tulane University, in making available much of the literature on the American lotus.

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Inflorescence of Philadelphus

H. W. Rickett

Occasional branches of the common *Philadelphus coronarius* L. of our gardens illustrate a transition from the cymose (determinate or basipetal) to the racemose (indeterminate or acropetal) type of inflorescence. The flowers of this shrub are typically borne at and near the ends of leafy branches (Fig. 1). At the tip of such a branch is a dichasium of three flowers, the central blooming first. The remaining flowers are characteristically paired on opposite sides of the branch; the leaves which subtend them are reduced gradually upwards from foliage leaves to minute bracts. The uppermost pair of axillary flowers opens after the terminal flower but usually before the lateral flowers of the terminal dichasium; thenceforth flowering is basipetal down the branch.

On the aberrant branches mentioned, which elongate more than the others, the flowers in the lower axils bloom first and flowering is acropetal; though on them also the terminal flower precedes the two immediately beneath it (Fig. 2). The character of the branch suggests that the change in order of flowering is brought about by physiological factors. One may suppose that in the rapidly maturing tip of the typical branch substances are formed which are concerned with flowering; in aberrant branches the greater degree of elongation delays development at the tip until after the lower axils have begun the production of flowers.

Whatever the factors involved (and their identification would seem a fertile field for experiment), we see here the ease with which the cymose may pass to the racemose inflorescence; a transition which implies that the order in which flowers open is of little or no morphological significance. This conclusion has been reached also in a consideration of the inflorescence of *Crataegus* (Rickett 1943). It may be objected that, since the apparently racemose branches of *Philadelphus* have terminal flowers, and since these are not the last to open, such branches are not true racemes. But, if this be granted, the same must be said of many inflorescences, commonly treated as racemes, which possess early-blooming terminal flowers (e.g. in *Campanula, Rubus, Berberis*).

Which is the more primitive in *Philadelphus,* the cyme or the raceme? The presence on all flowering branches of the terminal dichasium suggests the former. On the other hand, textbooks often present inflorescences in general as having been derived from branches bearing solitary flowers in the axils of leaves. A comparison of several species of this genus is of interest here. The following notes were made from specimens preserved in the herbarium of the New York Botanical Garden.[1]

[1] It should be understood that the inflorescences here described are characterized from specimens in which they appeared well developed. Naturally much variation is encountered, and the inflorescences here selected for description may not be representative of "typical" plants of their species. They do, however, represent the tendencies at work in the genus.

Figs. 1-6. Flowering branches of several species of *Philadelphus*. Fig. 1. Typical branch of *P. coronarius*. Fig. 2. Aberrant branch of *P. coronarius* on which the flowers opened acropetally. Fig. 3. Thyrse of *P. californicus*. Fig. 4. Flowering branch of *P. lewisii*. Fig. 5. Flowering branch of *P. hirsutus*. Fig. 6. Flowering branch of *P. argenteus*. Figs. 1 and 2 sketched from living plants; the remainder from the herbarium specimens indicated. The drawings are sketches rather than exact portrayals of individual branches; but the number and relative development of flowers on each branch are accurately copied.

P. californicus Benth. has flowers disposed in ample clusters which terminate leafy branches. Each cluster may be termed a thyrse; the sense in which this word is used will appear below. Each thyrse comprises a terminal dichasium of three flowers, below which are pairs of lateral branches likewise terminated by dichasia. The lower branches, which are subtended by foliage leaves, are often themselves compound, repeating the organization of the distal part of the main axis of the thyrse (Fig. 3). There is a tendency for the central flower of each dichasium to open earlier than those immediately beneath it. All branches of the thyrse seem to come into bloom approximately together; there is no marked acropetal or basipetal tendency.

P. columbianus Koehne, *P. lewisii* Pursh (Fig. 4), and *P. affinis* Schlecht. have flowers arranged much as in *P. coronarius* but borne on rather short branches which have only a few pairs of leaves. In *P. hirsutus* Nutt. the flowers are solitary or in three-flowered dichasia at the ends of short branches which have usually only one or two pairs of leaves (Fig. 5). In *P. argenteus* Rydb. the flowers are usually solitary at the ends of short lateral branches which bear a few pairs of leaves (Fig. 6).

Obviously such a series as that briefly sketched above may be read in either direction. One might assume that *P. argenteus* has the primitive inflorescence from which the more ample types have been developed by the production of axillary flowers and flower-clusters. Two considerations militate against such an hypothesis. First, *P. argenteus* is certainly the most specialized of the species here mentioned; reduction and condensation are evident in its leaves and branches. It would seem gratuitous to assume that the inflorescence — a system of branches — had here retained its primitive character while all the more generalized species attained a more specialized inflorescence. Second, the prevailing unit of flowering throughout these species is evidently the dichasium, a terminal structure.[2] The more ample inflorescences include more dichasia, which may terminate almost every peduncle, often to the exclusion of the single axillary flowers demanded by the conventional account of the phylogeny of inflorescences.

As a matter of fact, though the origin of inflorescences from flowers borne singly in the axils of leaves is expounded in a number of current textbooks, various students of this subject from Saint-Hilaire (1840) to Parkin (1914) and Woodson (1935) have proposed that the primitive arrangement of flowers was terminal and the racemose type of inflorescence derivative. Such a view makes the relationships of the flower-clusters described above easily grasped. For a working hypothesis, suppose that the terminal dichasium is ancestral in *Philadelphus*. This type of terminal inflorescence, which is capable of almost indefinite growth (e.g., in *Begonia*), must have become early limited to its three primary flowers, and sometimes to a single terminal flower. If several flowering branches, attached along a common axis, are early limited in their vegetative development by the production of flowers, the result is the arrangement seen in *P. hirsutus*. When the reduction of the terminal dichasium to a single flower becomes fixed, we have the solitary terminal flowers of

2 For the application of the term dichasium, see a previous paper (Rickett 1943).

P. argenteus. Still further reduction of the now lateral flowering branches (or, to put it differently, still earlier passage to flower production) leads to the axillary flowers of *P. coronarius*. This condensation is accompanied by a lack of dormancy in the new axillary buds, which open the same season as the leaves which subtend them. Some of the subtending leaves become reduced or entirely disappear, and the internodes between them become shortened.

From flowering branches formed in such a way, bearing flowers at the tip and in the axils of leaves or bracts along the sides (so as sometimes to simulate a raceme), we can arrive at the arrangement seen in *P. lewisii* and at the thyrse of *P. californicus*. The latter represents a condensation of the second order; i.e., not only are a number of the original flowering branches laterally disposed on a central rachis, but several groups thus constituted are similarly disposed on the main axis of the thyrse.

The racemose tendency has been observed only in *P. coronarius*, where it occurs as a consequence of the extreme reduction of lateral branches and of some physiological reconstitution. The tendency, however, is scarcely marked enough even here to justify the description of *Philadelphus* as having flowers "solitary, corymbose or racemose" (Small 1913), "terminal or axillary, corymbose, racemose or solitary" (Britton & Brown 1913), "in a terminal raceme or thyrse" (Jepson 1936), or "in einfachen oder aus Trugdöldchen zusammengesetzten Trauben" (Engler 1891). Such inaccuracies of description seem to be characteristic of modern treatment of inflorescence. Robinson and Fernald (1908) speak more accurately of *Philadelphus* as having "solitary or cymose-clustered flowers," and Munz (1935) uses substantially the same expression. In the species briefly surveyed above, the flowers may be accurately described as singly or in dichasia terminating leafy branches which are often reduced, or aggregated in thyrses. The thyrse is here defined as a compound flower-cluster of a more or less pyramidal form whose ultimate units are simple dichasia.

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THE NEW YORK BOTANICAL GARDEN,
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Book Reviews

STUDIES IN THE LIFE HISTORY OF THE SONG SPARROW II. THE BEHAVIOR OF THE SONG SPARROW AND OTHER PASSERINES. By Margaret Morse Nice. Trans. Linnaean Soc. New York, 1943, vol. 6, viii + 328 pp., frontispiece, 6 figs. $2.00, from the Society.

The second volume of the monograph on the song sparrow by Mrs. Nice provides an exhaustive account of the behavior of that species. It is her hope "that this book will serve as a guide to the study of bird behavior, showing, as it does, the general pattern of development and broad outlines to be expected, and giving a viewpoint and technique which should help others to intensive observation and study." Bird students are now so familiar with the methods and results of this undertaking that each of them knows in advance how the report will help him. Possibly the chief distinction of this study is the author's early discovery and resolve to follow the principle that "it is all-important to *see* and *record exactly* what a bird does. Instead of saying one bird 'threatens' another, we should describe precisely the notes and gestures."

Adherence to this rule along with active search for significant questions to be answered made the years devoted to this bird profitable beyond ordinary expectations. So many facts resulted that their cumulative weight makes a convincing story of the life of a song sparrow. Choice of a species and an area adapted to study by trapping made the effort especially fruitful. Even the practice of working the facts into published form as they were gathered contributed importantly to the value of the final report. The two volumes contain evidence bearing on nearly every topic involved in the responses of a song sparrow to elements in its surroundings, whether animate or inanimate. The second one deals especially wiith the instinctive elements in activities, their development and maturation.

In preparing accounts of species it has become customary to make more or less complete reference to similar topics as known for other kinds of birds. These references have interest, but it is not always clear just how they contribute to the story of the species being treated. Traits of structure and behavior do not necessarily vary together, and it may be too much to expect selections from widely differing studies to reinforce satisfactorily the story of one species. Comparisons with the same species in other regions or closely related species in the same genus, possibly in the same family, would be likely to bring more valuable results than would selections from a multitude of species studies with remote bearing. The latter kind of compilation is valuable in proportion as it is encyclopedical and approaches completeness. Mrs. Nice has made this kind of study and has combined a part of the results with her song sparrow story. My own preference is to keep these two kinds of work separate. Greatest needs now are for thorough accounts of single species and comparisons among closely related ones. These seem to be more satisfying when not diluted with too much reference to other animals.

Prominence is given through the work to the opinions of a few recent workers, especially Lorenz, the Heinroths, and Tinbergen. The resulting close adherence to fairly unified authority appears to simplify the problems of behavior. This is somewhat of an advantage, though it necessitates the omission of much information and opinion that should be useful in such a study. Recent, novel expositions are not necessarily the most satisfactory.

It seems strange to find scant reference to the reported observations on passerine birds as studied by the older American ornithologists. The apparent explanation is that these persons have not expressed their findings with the vocabulary now recognized. Also, they have made the study of behavior subordinate to the geographic phases of natural history. They have, however, published a great deal of evidence that should be incorporated into the current interpretation of birdlife. Morphology, physiology, and geography may well be employed along with observations on the live birds in reaching

well-based conclusions as to behavior. A notable feature of this study is that only live birds were employed.

Evidence is arranged according to a finely divided outline which provides thorough treatment, but the resulting disjunction and repetition is sometimes tiresome. The aim for precision in presenting facts sometimes results in excessive refinement, though this is hard to avoid when examples are scarce. The repeated use of the term median where mean would be expected is not clear.

The elaborate discussion of evolution of song in female birds (p. 129) expanded from a symmetrical chart is an example of a way not to analyze behavior of animals. The outline was developed by discussion, the species or groups were assigned to the various compartments of the plan. This provides a classification of types of song but indicates no evidence of the course of evolution concerned if indeed there has been a separate evolution for this trait.

In some other examples there is a forced reasoning beyond the basis of fact supplied by observation. It is not to be expected that all groups of observations concerning the habits of birds would lead to satisfactory explanations of conclusions. The whole subject of bird behavior is so intangible as to encourage reluctance in accepting casual explanations of the meaning of the traits which we seem to detect. One indicator of this is the frequency of disagreement among current writers as to significance of the elements in bird behavior. Each student tends to see meanings different from those suggested by preceding authorities.

The work on the song sparrow can be accepted as a most useful aid in studies to be conducted along the lines treated. This, however, does not mean that work with other species should be conducted on the same plan, even if that be possible, or that other references can be displaced by it. Another worker can profit most from it as supplying clues as to things to look for rather than as a set of conclusions to be verified or denied. The need is for independence in reporting and this requires independence in seeing as well as in interpreting.

Especially useful are tables of appearance and duration of activities in the young bird, of singing through the nesting cycle, of innate and learned elements in activities, of stages and activities in reproductive cycle, of methods of intimidation. Other useful items are the list of birds which exhibit distraction display, a list of vocalizations, and the outline figures which show attitudes. Nearly everyone seriously interested in live birds will be grateful for this monograph and will refer to it constantly. Our chief debt is to the author, but the society which sponsored publication also deserves our thanks.—JEAN M. LINSDALE.

NORTHERN FISHES. By Samuel Eddy and Thaddeus Surber. The University of Minnesota Press, Minneapolis, Minn. 1943. xi + 252 pp., 93 figs. (9 in color). $4.00.

This book soundly achieves its major objective of providing scientists and sportsmen with a means for learning selected fundamentals about fishes, fishing, and fishery management in northern waters. The area of primary application for the text centers in Minnesota but, of course, the principles and the fishes have a wider range. Summaries are given of the fields of aquatic ecology and fish management—the ideas and practices of increasing, conserving and maintaining the fish supply. Also incorporated are keys to the fishes, which are perhaps a little too technical and are lacking in diagrams of the more difficult identification characters. Brief descriptions of habits and relationships are given in the accounts of the species. The broad experience of the authors in both the scientific and popular phases of their subject has enabled them to contribute a largely authentic and readable account. Particularly unique and commendable, from the lay point of view, is the treatment of the limnological material in the first, general part of the publication. These early chapters of the book dealing with fish management are, however, inadequately documented. This leads not only to uncertainty as to source for many items of information but also tends to establish as true and known many things

which as yet are uncertain or are at least poorly or only locally demonstrated. Furthermore, not all of the references cited are included in the bibliography.

Occasional poor word choice obscures actual meaning. For example (p. 6) it is written of the paddlefishes that "They swim slowly with a spiral motion." Regarding lake surveys a list of the things usually studied is followed by the overbold statement (p. 10): "The results constitute an inventory of all conditions for fish life."

Interestingly, eels are accused of having lost all or most of their scales (p. 37) but later recover them (p. 172). The bald analogy of fish production in a body of water to crop production on farm land is unhappily perpetuated. This comparison, unless qualified, gives an erroneous impression since most farm crops are annual ones and necessitate the yearly planting of seed and entail a complete harvest. Fish cropping more closely parallels certain aspects of cattle raising or of forest management.

Total available food is indicated as the key growth retarding factor in crowded populations. Although the complexity of the problem is stated, no mention is made of the possible direct action, quite independent of available food, of crowding in causing stunting as has been shown for other animals.

Several methods of measurement are loosely or incorrectly defined for diagnostic purposes in fish identification, even for application to the keys included in the present work. Examples are those for *standard length* (p. 35) which gives the wrong impression and *eye in head* which is not very precise. Other features are inadequately or coarsely indicated on Diagram 1; *these are length of caudal peduncle, snout,* and *length of head.* Other critical key characters are without definition and presuppose some knowledge of ichthyology.

Most of the numerous halftones are good but some are poor, particularly among the cyprinids. On multiple species plates the individual figures are not lettered and thus do not adequately tie in with the figure headings. The color plates are disappointing, being particularly annoying in the poor touch-up work done on them and in the choice of specimens for photography.

Errors in classification and misstatements and perpetuation of previously published mistakes as to distribution are discussed and corrected by Carl L. Hubbs. (*In press,* Copeia).—Karl F. Lagler, University of Michigan.

Plant Viruses and Virus Diseases. (Second Entirely Revised Edition). By F. C. Bawden. Volume xiii of A New Series of Plant Science Books, Edited by Frans Verdoorn, and Published by Chronica Botanica Co., Waltham, Mass.; G. E. Stechert & Co., New York City, 1943. 294 pg., 48 illus., $4.75.

The second edition of Dr. Bawden's survey of the nature and action of the plant viruses, as explained in the preface, was necessary as a result of the advances in the researches dealing with viruses, as well as the loss of the type during the invasion of the Netherlands. With the addition of 11 figures and an increase of 22 pages of text, in spite of the use of smaller type, the presentation of the plant viruses seems admirable and thoroughly adequate.

The structure of the book itself is set on the same outline used for the first edition. The main alterations occur in the revision of the Chapters on "Relationships between Viruses and their Insect Vectors," "Methods of Purification," "Inactivation of Viruses," and the separation of "Classification" and "Control" into separately discussed chapters. All the other chapters have, however, the newer information interpolated in a manner which is seldom evident, and which brings the interpretation of the whole up to date.

The text gives definite evidence of a biochemical leaning in the arrangement and presentation of the subject matter. This particular phase is greatly improved in the second edition by an explanation of the methods and the basis for interpretation of results frfom techniques not familiar to most plant scientists. The nature of the viruses, their size, structure, chemical composition, serological reaction, optical and physical

properties are not only more clearly explained and correlated but the basis for the acceptance or refutation of various theories is adequately explained.

In fact, the outstanding feature of the book, aside from the collection and digestion of a monumental amount of information, seems to be the completely unbiased and thoroughly logical manner in which controversial matters are considered and the various theories disposed of or their particular advantages stressed. The searching analysis of experimental data and the conclusions drawn from them by an expert in the field should serve not only to prevent the student from accepting doubtful or unsupported theories, but more especially as illustrations in the methods of analyzing and appraising research work. This is especially evident in the discussion of the classification and nomenclature of the viruses.

While the number of typographical and grammatical errors is not large, some statements are liable to cause a student to wonder at the author's meaning. On page 19, what is, ".... the time of maximum rate of appearance of local lesions...." On page 72, in discussing the rate of movements of viruses transmitted mechanically or by insects, the sentence—"The two type of viruses, therefore, seem to behave differently after entering infected plants."—seems to contain confusing ideas at the beginning and at the end. At the bottom of pages 10 and 279 the substitution of "than" for "that" is not too evident. On page 122 the inclusion of the equation for the dilution curve "$y=N(1-e^{-ax})$" and the statement, "Chester's results.... are better suited by a change in *a* than by a change in N.", without explaining the meaning of components of the equation is of doubtful value. On page 264, in the sentence "as different insects are transmitted by insects having different habits...." the error would be apparent. One is, however, pleased that idioms are avoided, but struck rather forcibly by the collection on page 267 where few American readers will be able to take "chitted" "riddles," and "ware" without at least a pause. In addition many will object to the use of "infection" meaning the course of the disease, and the authors extension of the term "immune."

The book, although described as not a textbook, will certainly be essential for any course in virus diseases of the plants. The only short-coming or reason for failure to employ Plant Viruses and Virus Diseases as a text would be the complete lack of the description of the few rather general diseases which have served as the basis for the great majority of the work reported. The second edition is an improvement over the original and presents as excellently balanced account of the viruses. The students and especially the instructors will only hope that Dr. Bawden will continue to revise his work as thoroughly every four or five years.—G. C. KENT, Iowa State College, Ames, Iowa.

FUNDAMENTALS OF CYTOLOGY. By Lester W. Sharp. McGraw-Hill Book Company, Inc., New York, 1943. x + 270 pp., 176 text figures. $3.00.

For many years there has been an outstanding need for an elementary introduction in the English language to the subject matter, principles and theories of cytology suitable for students entering biology. Professor Sharp has attempted to fill this need by the present volume, but it may be questioned whether the "Fundamentals of Cytology" will prove to be a thoroughly satisfactory aid to the teaching of basic cytology. This doubt arises not so much because the book deals almost exclusively with classical cytology and cytogenetics, but because it is in effect a remarkably condensed yet detailed summary of much factual material rather than a rigorously selected and balanced account of the fundamentals of general cytology.

The introductory chapter sketches the position of cytology in modern biological science, emphasizing the experimental (but not the deductive) nature of twentieth century cytology. There are five chapters which deal primarily with cellular morphology, one devoted to aspects of cell division, a chapter on meiosis, three chapters on the cytology of reproduction, and six chapters alloted to cytogenetic topics. Thereafter follow somewhat more than nine pages of suggested readings, and ten pages of index.

In general the subject matter is derived overwhelmingly from the botanical sciences, a fact which tends to lend bias to discussions which should be of more general nature

and scope (viz. chapters 15 and 16 on cytological aspects of hybridity and of taxonomy). While the text is skillfully and lucidly written throughout, it is overly burdened with an unnecessarily complex technical vocabulary. Considering the not infrequent occurrence of little-used terms such as "*amphitene*," "*euchromocenter*," "*kinoplasm*," "*parthenote*," and so on, it is surprising that Sharp uses "organ" for cell parts in lieu of the less ambiguous "organelle." A lamentable feature of the terminology of this book is the use of "monoploid" for the familiar and established "haploid," although "haplosis" is employed in the text rather than "monoplosis."

The book is at its best in the chapters devoted to chromosomes, meiosis, and cytogenetics, although the treatment of segregation, crossing over and chiasmata, sex chromosomes, and parthenogenesis seems inadequate for a basic textbook of this type. Less satisfactory are the chapters on the properties of protoplasm and the cytology of reproduction in animals (chapters 4 and 9, respectively). These latter chapters seem much too sketchy and elementary, and for the most part the information presented does not go beyond that of a good introductory course in biology.

There is little attention paid to current cytological theory in this book, but it might be argued that theory and additional information filling in the gaps mentioned above may be gleaned from class discussion and the suggested readings. Unfortunately the latter readings are often ill-selected. Not cnly are the references chiefly to botanical literature, but outmoded works of Agar, Doncaster, Hegner, Heidenhain and Lundegårdh are cited whereas such recent and authoritative works as Darlington's "Evolution of Genetic Systems," White's "Chromosomes," Sturtevant and Beadle's "Introduction to Genetics," Vandel's "La Parthénogénèse" and Hirsch's monograph on Golgi bodies—by way of illustration—are omitted. The journal references are in many instances equally unsatisfactory.

Factual errors and misprints are remarkably few and for the most part too trifling for mention. However, exception must be taken to some of Sharp's statements. It is surprising to read that chromatin is a chemical substance (pp. 26, 28), that at the kinetochore of every chromatid, as the chromosomes take up their equatorial positions, "there appears a small mass of material which gradually extends poleward through the spindle substance as a so-called *tractile fiber*" (p. 62), and that "independent inheritance is exhibited only by characters having their differential genes in different chromosome pairs" (p. 174). It is perhaps equally surprising that the statement is made that "for reasons not well understood this condition (polyploidy) is very rare among animals but it is of frequent occurrence in plants. . . ." Certainly some mention of the restrictions placed upon numerical alteration of chromosome sets by sex chromosomes in gonochoristic organisms is in order at this point.

All in all, however, Professor Sharp has written a lucid and detailed book which should be of assistance in the teaching of introductory general cytology. For its successful use, however, the book demands instructors of more than average breadth of knowledge and skill in emphasizing such general principles as form the background of modern cytology. This is, after all, as it should be, and Professor Sharp has lightened the task by means of the excellent summaries and general conclusions at each chapter's end.—KENNETH W. COOPER, Princeton University.

THE BOLETACEAE OF NORTH CAROLINA. By William Chambers Coker and Alma Holland Beers. University of North Carolina Press. Chapel Hill. 1943. viii + 96 pp. Frontispiece + 65 plates (6 colored). $7.00.

Although the boletes are among the most striking of the fleshy fungi, they are also among the more troublesome to classify. Their tendency to putrefy and to be infested with larvae makes them difficult to preserve and many of the criteria by which the various species are distinguished are ephemeral and must be observed in fresh specimens. Hence the interpretation even of properly dried and carefully annotated specimens presents many problems. Since the great majority of the species are of wide distribution, the present volume will be of service to students throughout most of the eastern United

States, and will help those who are inexperienced to decide what notes must be made while the specimens are fresh.

The treatment is extremely conservative. All boletes are referred to the three long-established genera *Boletus*, *Boletinus* and *Strobilomyces*. No reference is made to recent revisions of the family other than occasional citation of Murrill's and Snell's names as synonyms and such citation is far from complete. The individual mushrooms are referred to as "plants" and this usage is defended, despite its admitted inaccuracy, on the ground that the use of the more precise terms which are commonly applied is an affectation.

There are two keys. In the first, emphasis is placed on features which are likely to be noted by the experienced collector, with color subordinated; in the second, color dominates. Some species will doubtless lend themselves better to one treatment than to the other; together they should prove more helpful than either alone.

Three new species and four new varieties, all in *Boletus*, are proposed without Latin diagnoses, hence they are technically *nomina nuda*. In addition, there are four new combinations, three in *Boletus* and one in *Boletinus*. The photographs are clear and helpful and the color plates, illustrating twenty species, are particularly successful both in execution and reproduction.

Since the plates and their legends, occupying nearly half of the book, are not numbered, the volume is larger than the number of pages cited would seem to imply.—G. W. MARTIN, State University of Iowa.

A DICTIONARY OF THE FUNGI. By G. C. Ainsworth and G. R. Bisby. Imperial Mycological Institute, Kew, Surrey. British Publications Co., Pittsburgh, Pa., 1943. viii + 359 pp., 138 figs., $7.50.

Mycologists have long been without a convenient source of reference and have been dependent solely on large and voluminous indices, catalogues etc. This handy *Dictionary* will therefore be a most welcome addition to the personal libraries of all mycologists as well as those of many botanists, biologists and others in need of mycological information. Even a brief examination of this book will convince the interested reader of its indispensable character both as a nomenclator and as a dictionary.

Most entries are represented by the numerous generic names (7000) in use prior to the end of 1939, their assigned systematic positions, distribution, synonymy, number of species and recent important references. Although the genera of bacteria and lichens are not detailed, excellent summaries of these groups are included among the longer sections dealing with general, ecological, applied, historical and systematic aspects of mycology. A noteworthy feature is the consistent adherence of the authors to the International Rules of Botanical Nomenclature. With few exceptions all text matter has been written in Basic English. Frequently cross references aid the reader in locating related entries and information, although under *species*, for instance, no indication is given of the subspecific units discussed elsewhere. Included also are all mycological terms, both English and foreign, as well as common and scientific names of important fungi, etc. Representative organisms and many morphological details are illustrated on the ten plates. Professor G. W. Martin's well known and tested *Key to the Families of Fungi* is appended.

Beyond its immediate serviceability, *A Dictionary of the Fungi* readily discloses the present status of mycological knowledge, which is far from being satisfactory. In the light of this situation, the authors deserve particular credit for having completed their difficult task so well.—THEO. JUST.

V

The American Midland Naturalist

Devoted to Natural History, Primarily that of the Prairie States

Founded by J. A. Nieuwland, C. S. C.
Edited by Theodor Just

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Contents

Vol. 31 | MAY, 1944 | No. 3

NOTE: THE AMERICAN MIDLAND NATURALIST, published by the University of Notre Dame, is primarily, though not exclusively, devoted to the Natural History of the Middle West. A wide selection of papers on botany, paleontology and zoology is published in bi-monthly issues, three of which make up a volume.

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The *American Midland Naturalist* is indexed in the INTERNATIONAL INDEX.

Entered as second-class matter at Notre Dame, Indiana. Acceptance for mailing at special rate of postage provided for in section 1103, Act of October 3, 1917, authorized on July 3, 1918.

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